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Top astrophysicists uncover **how** and **why** it's sooner than we initially thought

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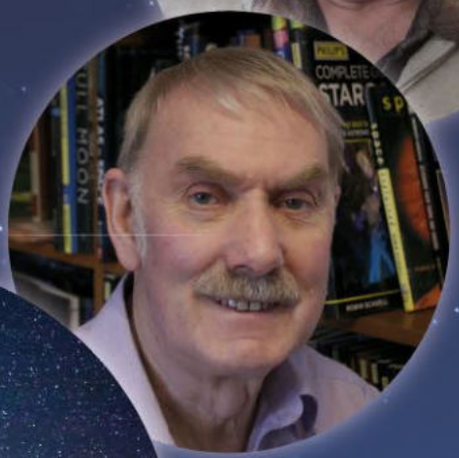
ROBIN SCAGELL



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Pluto's status could be up for review again thanks to new research

Welcome

The end of the universe is nigh – at least that's according to cosmologists. This issue, **All About Space** chats to the scientists who have made some progress in not only working out when the cosmos will meet its fate, but also how. And it's all thanks to the Higgs boson; the subatomic particle that gives everything in the universe its mass. Turn to page 16 for the latest in astrophysical research.

This month we wanted to give you an observing companion now that the darker skies are drawing in much faster, so we've teamed up with book publisher HarperCollins to give you its best-selling 2018 *Guide to the Night Sky* absolutely free with this issue.

So, if you have purchased the magazine from any of our UK stockists you now have the best observing tips from astronomers Storm Dunlop and Wil Tirion at your disposal. From the top events to see during the remainder of the year to easy-to-use sky charts, this exquisite guide is perfect for seeking out those night-sky treasures whether you're a naked-eye observer or are armed with a telescope or binoculars.

Elsewhere in the issue we discover the mini-moons that played a huge part in the evolution of our planet, chat to NASA astronaut Greg Johnson about his time in space and reveal new Apollo photos that you didn't get the chance to see during the Moon landings.

Enjoy the issue!

Gemma Lavender
Editor

Our contributors include...

Colin Stuart
Author & astronomer
Colin chats to the cosmologists who have worked out how – and most importantly, when – our universe will meet its fate, and why it's sooner that we thought.

Libby Plummer
Science & technology reporter
According to recent research, tiny moons around our planet likely assisted in our evolution. Read Libby's report over on page 32.

Lee Cavendish
Staff writer & astronomer
Pluto could actually be made of comets, according to a new study. But what does that mean for its status? Lee reveals all on page 52.

Stuart Atkinson
Astronomer & author
Stuart reveals what you can observe this month, and provides you with the tips and tricks to ensure that you get the best views of Mars and July's lunar eclipse.

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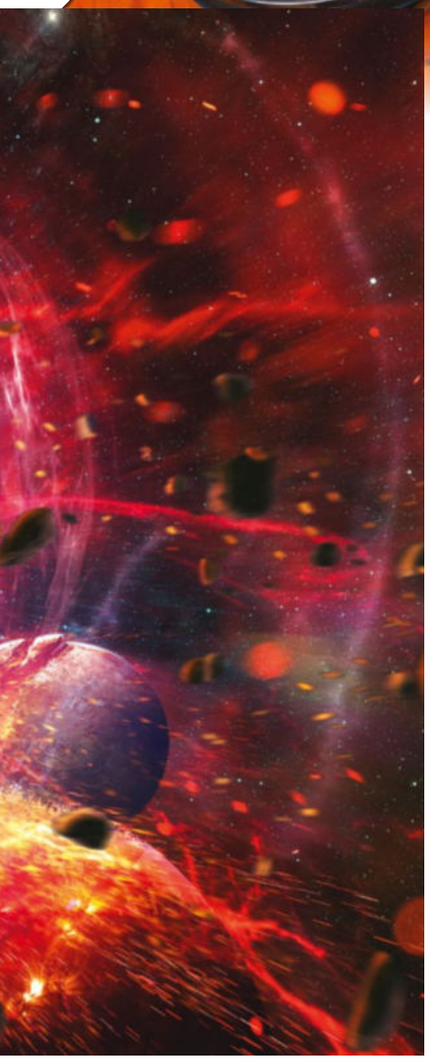
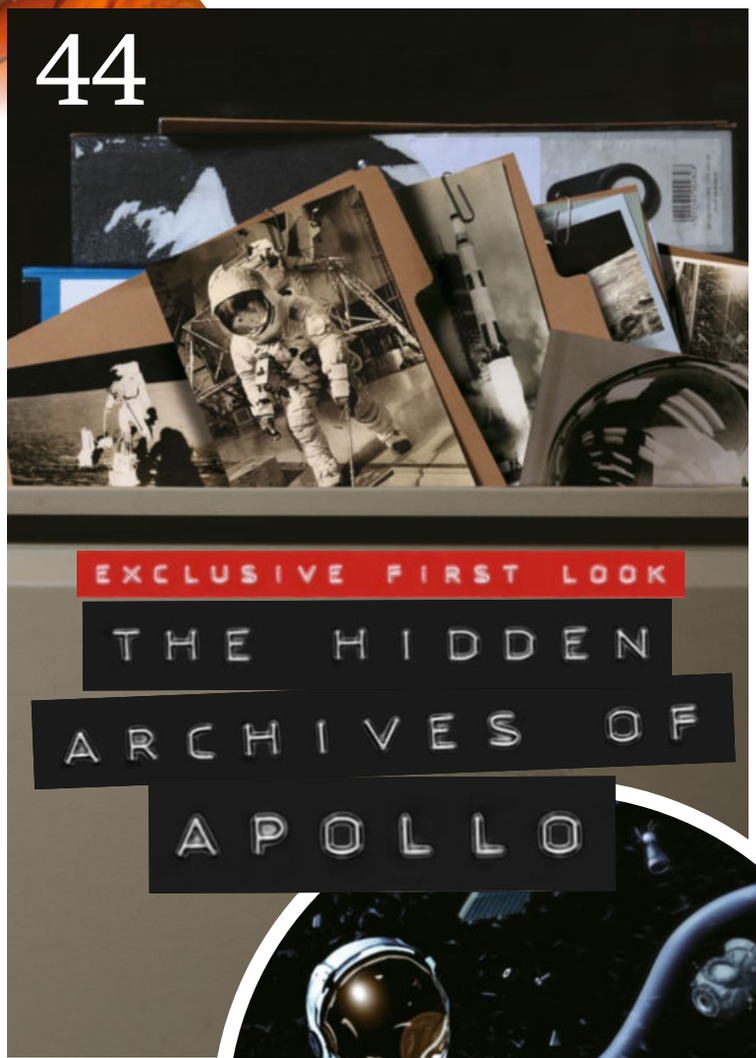
FEATURES

TURN TO **PAGE 50** FOR DETAILS

"I didn't think I'd get two flights. I thought at the time that I'd only get one"





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At work under the Milky Way

Behind the Atacama Rover Astrobiology Drilling Studies (ARADS), robot, the Moon begins to rise. The buggy is busy on its 2017 season of field tests in Chile's Atacama Desert. Meanwhile, the Milky Way is visible in the night sky.

The aim of ARADS is to design tools and techniques that could be used to one day search for life on Mars or other places in the Solar System. This image shows a prototype rover which combines the ability to move across the surface, drill down to collect soil samples and feed them to several life-detection instruments on board. Chile's Atacama Desert provides one of the most Mars-like environments on planet Earth.

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Galactic embrace

Locked in a spellbinding, swirling dance are two interacting galaxies, NGC 5426 and NGC 5427, which together form an intriguing astronomical object named Arp 271. The image was captured by the Visible Multi-Object Spectrograph (VIMOS), which was affixed to the European Southern Observatory's (ESO) Very Large Telescope before it was decommissioned during March of this year.

During its 16 active years VIMOS has helped astronomers to uncover the wild early lives of massive galaxies, observe awe-inspiring triple-galaxy interactions as well as explore some of the deeper cosmic questions, such as 'how did the universe's most massive galaxies grow so large?' VIMOS also had the special talent of capturing detailed information about hundreds of galaxies at once. It was able to collect the spectra – the chemical footprints from an astronomical object's light – of several galaxies throughout the universe, showing how they formed, grew and evolved.

The Space Station's new crew

Astronauts Sergey Prokopeyev of Russian Space Agency Roscosmos (bottom left), NASA's Serena Auñón-Chancellor (bottom right) and the European Space Agency's (ESA) Alexander Gerst (bottom centre) are the International Space Station's newest crew members. In this image they can be seen on a video monitor as they talk to family and friends at the Moscow Mission Control Center in Korolev, Russia, a few hours after the Soyuz MS-09 docked to the Space Station on 8 June. They can be seen with Commander Drew Feustel of NASA (top centre), astronaut Ricky Arnold of NASA (top right) and Oleg Artemyev of Roscosmos (top left).

ESO, inspired by *Interstellar*

La Silla observatory in Chile, which is owned by the European Southern Observatory (ESO), looks undeniably photogenic from every angle. That's how ESO photo ambassador Petr Horálek was able to capture an unusual, yet creative perspective such as this one.

"I was wondering if it was possible to capture the mystical colours of the universe without complicated equipment," he explains, adding that he was initially inspired by one of the promotional posters for Christopher Nolan's film *Interstellar.* "At La Silla, you can really feel – and capture – interstellar moments!"

Horálek succeeded. The majestic band of the Milky Way galaxy can be seen blazing across the sky, creating a cosmic bridge between two of La Silla's resident telescopes: the 3.6-metre telescope (left) and the Swedish-ESO Submilimetre Telescope (right). In the image, the Large and Small Magellanic Clouds – two nearby galaxies – can be seen, sitting together 'above' the galactic plane in the upper-right-hand corner of the shot. Bright splashes of red in the middle are the beautiful Gum Nebula, while the bright dot in the lower left of the image is planet Jupiter.

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Chaos on Jupiter

Yet another stunning capture from NASA's Juno spacecraft, this colour-enhanced shot reveals the swirling cloud belts and tumultuous vortices within Jupiter's northern hemisphere. At the time, Juno was roughly 15,500 kilometres (9,600 miles) from the gas giant's cloud tops.

Jupiter is famous for its chaotic and turbulent atmosphere, and this portion of the planet is of no exception. The darker cloud material signifies formations deep inside the world, while the brighter systems are most likely ammonia or ammonia and water mixed with a sprinkling of unknown chemical ingredients at a higher elevation.

The bright oval at the bottom centre is a stand-out feature in the image. In ground-based telescope observations it appears uniformly white, but with the spacecraft's JunoCam we're able to see a fine-scale structure within the weather system.

Blue dune on Mars

This region of Lyot Crater, captured by NASA's Mars Reconnaissance Orbiter (MRO), shows a field of classic barchan dunes. These sand dunes usually accumulate on the floors of craters.

The focus of this image, though – and just to the south – is a large dune that's much more complex in structure. It appears turquoise blue in enhanced colour, being comprised of finer material and/or having a different composition than the ones that surround it.

Telescopic giants of Chajnantor

Giant telescopes are usually comprised of several mirrors or antennae, and the European Southern Observatory's (ESO) Very Large Telescope (VLT) which is located at Paranal Observatory in Chile is of no exception. It's made up of four main telescopes along with four smaller, movable auxiliary telescopes – that's eight individual structures in total. While it holds the title of 'very large', this gigantic structure is dwarfed by another – the Atacama Large Millimeter/submillimeter Array (ALMA), which comprises of a whopping 66 antennae and sits on top of the Chajnantor plateau in the Chilean Andes.

Here are two such antennae. Up close they're impressive in size – and, in order to transport them up to their prime location on top of the plateau at an altitude of 5,000 metres – two strong vehicles are needed. Enter Otto and Lore.

These two ALMA Transporters, which have been painted a vibrant orange-yellow in this image, have been designed and built especially for the job; they're 20 metres long, 10 metres wide with 28 wheels. They've been built to survive the harsh environment of the Atacama Desert, and are able to master the rugged Chilean terrain with ease and astonishing millimetre accuracy.

Universe's 'missing matter' is finally found

Scientists clear up a mystery by locating the elusive third of ordinary matter created when the cosmos was born

Astrophysicists have finally pinned down the location of a huge amount of missing ordinary matter, going a long way to solving a mystery dating back some 20 years. Scientists at the University of Colorado Boulder say the missing matter is found in the space between galaxies. They made the discovery by observing a distant, ultra-bright black hole.

The study was inspired by a stark discrepancy between the amount of ordinary matter calculated to have been created during the Big Bang and the amount that could be seen with telescopes today. Up until the recent findings, only two-thirds of ordinary matter, known as baryons, had ever been located, leaving a big question mark over the remaining third.

By pointing a series of satellites skywards, the scientists were able to monitor the radiation emanating from a distant quasar. First of all they used the Cosmic Origins Spectrograph on the Hubble Space Telescope to work out where the missing baryons may be located. They then used the European Space Agency's X-ray Multi-Mirror Mission satellite for a closer inspection.

They found that the lost matter exists as thin, hot clouds of oxygen gas at temperatures of about a million degrees Celsius (about 1.8 million degrees Fahrenheit). It was just as Michael Shull, a co-author of the study at the university, had predicted in 2012. Back then they had reckoned on the missing 30 per cent being in a web-like pattern of space called the warm-hot intergalactic medium.

As expected, the news has been greeted with a lot of excitement. "We found the missing baryons," says Shull. The findings will now need to be confirmed by monitoring more bright quasars. But the ability to record how radiation from a quasar passes through space and how it changes the light from that black hole is a stunning breakthrough.

It goes a long way to answering questions about how the universe began, but it also poses conundrums of its own. "How does [ordinary matter] get from the stars and the galaxies all the way out here into intergalactic space?" asks Charles Danforth, a research associate at the University of Colorado Boulder. "There's some ecology going on between the two regions and the details of that are poorly understood."

The new study appears in Nature and it was led by Fabrizio Nicastro of the Italian Nazionale di Astrofisica – Osservatorio Astronomico di Roma and the Harvard-Smithsonian Center for Astrophysics. The baryons, however – which make up all of the physical objects in existence from black holes to the stars – are not to be confused with dark matter.

"We found the missing baryons"

Einstein's theory of general relativity passes first extragalactic test

The much-heralded theory has been tested on a large scale for the first time

Time and time again, Albert Einstein's general theory of relativity has been shown to be correct, and now – 103 years after it was proposed – it has been validated once more, this time in a distant galaxy.

Researchers using data from the Hubble Space Telescope and the European Southern Observatory's Very Large Telescope (VLT) found that gravity in the galaxy ESO 325-G004 behaves in the same way as it does in our Solar System. In particular, it fits in with the predictions of the German-born scientist who said that objects with considerable mass can bend the light of distant objects, thereby deforming space-time (known as gravitational lensing).

As such, the study team used the VLT to measure the speed of the stars within the galaxy to calculate its mass. They then used Hubble to observe gravitational lensing on the galaxy, which is 500 million light years from Earth, to see how strongly gravity was bending the light reaching Earth. By calculating how light (and therefore space-time) was being distorted by the mass, they worked out that the galaxy's mass was within nine per cent of what the general theory of relativity predicted.

It helps put to bed alternative models of gravity by lending extra weight to the existence of dark matter and dark energy, supporting the standard model. "The universe is an amazing place, providing such lenses which we can use as our laboratories," says study team member Bob Nichol of the University of Portsmouth.

An image of the galaxy ESO 325-G004 with an inset showing the distortion of light from a more distant source

The finding will be confirmed by monitoring bright quasars (pictured)

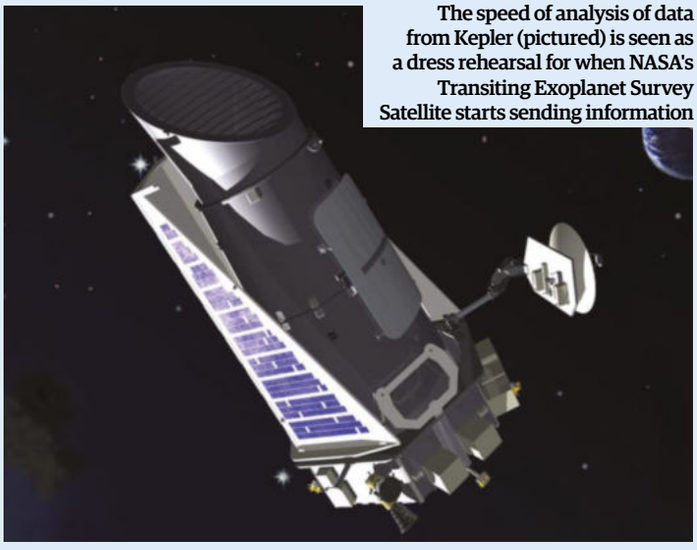
Exoplanet candidates found in record time

Time taken to identify dozens of new planetary candidates has been slashed

Almost 80 new exoplanets have been discovered by scientists analysing data from the follow-up mission to NASA's Kepler Space Telescope. The planetary candidates were discovered by K2 researchers in just two weeks, making it a record-breaking feat.

The scientists looked at graphs of light intensity, known as lightcurves, from each of the 50,000 stars they analysed. They found that 30 of the candidates were of the highest quality, while 48 could potentially be false positives. There were also 164 eclipsing binaries and 231 other regularly periodic variable sources.

One of the exoplanets appears to orbit the bright star HD 73344 every 15 days and, as well as being scorchingly hot with temperatures reaching 1,300 degrees Celsius (2,372 degrees Fahrenheit), the body could be about 2.5-times the size of Earth and ten-times as massive.



The speed of analysis of data from Kepler (pictured) is seen as a dress rehearsal for when NASA's Transiting Exoplanet Survey Satellite starts sending information

"We think it would probably be more like a smaller, hotter version of Uranus or Neptune," says Ian Crossfield, an assistant professor of physics at Massachusetts Institute of Technology, who co-led the study with graduate student Liang Yu.

The speed of the discoveries from K2's 16th and 17th observing campaigns was made possible thanks to tools developed at MIT. It is being seen as crucial in enabling astronomers to monitor patches of sky before a planetary candidate passes out of sight.

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Exploding volcanoes explain weird Mars rock

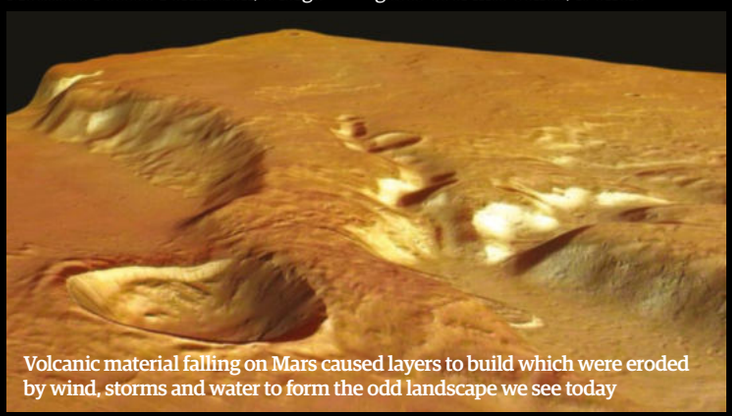
The eruptions went on to shape the strange landscape that is Medusae Fossae and led to a planet-wide ocean

Huge volcanic eruptions may have changed the face of Mars over the course of 500 million years, and even caused an ocean to wash over the entire planet. That's the conclusion of a new study by Lujendra Ojha, a planetary scientist at John Hopkins University in Maryland, USA, who says it has the potential to alter scientific understanding of Mars' make-up.

Ojha's research centred on the Medusae Fossae Formation, a large geological unit of probable volcanic origin on Mars. Its hilly, steep nature contrasts with the flatter surrounding environment but, by looking at radar and gravity data, Ojha and his fellow researcher, Kevin Lewis, found the area to be less dense than the rest of the Red Planet's crust.

Since the density near-matched the terrestrial rock ignimbrite that forms on Earth after volcanic gases cool into solids, it offers evidence that Medusae Fossae was formed by deposits or porous rock from volcanic eruptions staring 3 billion years ago. For it to have affected such a wide area, however, means the explosions would have needed to be gigantic. If that was the case, then huge amounts of carbon dioxide and methane is likely to have been ejected into the atmosphere, and the greenhouse effect would have had widespread consequences.

Most crucially this would have led to a global ocean that was nine centimetres deep. Meanwhile, the atmosphere would have been affected by hydrogen sulphide and sulphur affecting the potential for life. It also drives a nail into conspiracy theories that Medusae Fossae was the landing site for UFOs, but that was always a far-fetched idea.



Volcanic material falling on Mars caused layers to build which were eroded by wind, storms and water to form the odd landscape we see today

The Tiangong-2 space lab is a prototype of a space station China seeks to launch within four years

China lowers – then raises – space lab orbit

Why was China's Tiangong-2 space lab brought close to Earth for just ten days?

China lowered the orbit of its Tiangong-2 space lab in June - only to raise it again in a move that has baffled many sky-watchers. Jonathan McDowell, an astronomer at the Harvard-Smithsonian Center for Astrophysics, was among those questioning the motivation: "OK now that's weird," he tweeted. "New orbit data for Tiangong-2 shows it back in the 390km [242 mile] orbit after spending ten days in the lower 295km [183 mile] orbit. Wonder what that was about??".

Many experts had believed that China was seeking to de-orbit the lab, which was launched on 15 September 2016 as a testbed for technologies set to be used in the Chinese large modular space station planned for launch before 2022. It was thought the country wanted to avoid the fuss around Tiangong-1, which crashed down into the Pacific Ocean after burning up in the skies above Earth when it entered the atmosphere in April.

McDowell later mused that China was "probably just testing out the spacelab's engine reliability after 2 years in orbit as part of end-of-life tests." Such a scenario makes sense, but it has certainly got the rest of the world talking.

NASA's new plan to destroy potentially harmful asteroids

The space agency has outlined its five-step plan to prevent asteroids from hitting Earth

Hollywood fiction looks set to become fact as NASA and the US government set out their ten-year plan to protect Earth from asteroids. It is detailed in a 20-page report titled the National Near-Earth Object Preparedness Strategy and Action Plan which discusses what should be done if an asteroid or comet comes within 30 million miles of our planet.

Near-Earth objects (NEOs) are observed at the Jet Propulsion Laboratory in Pasadena, California, but work is ongoing to identify the best kinds of spacecraft needed to nudge them out of harm's way or break them up. The plan also seeks to enhance NEO detection, tracking and characterisation, while also improving predictions, increasing international cooperation and establishing NEO impact emergency procedures.

"An asteroid impact is one of the possible scenarios that we must be prepared for," said Leviticus Lewis, chief of the Federal Emergency Management Agency's National Response Coordination Branch.

Even so, the proposals stop short of allowing astronauts to spearhead the efforts. Instead, robotic spacecraft will do the dirty work. "Part of what this action plan is about is to investigate other technologies, techniques for both deflection and disruption of the asteroid," NASA's planetary defence officer Lindley Johnson added.

An artist's impression of an asteroid smashing into the Earth, with devastating results

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			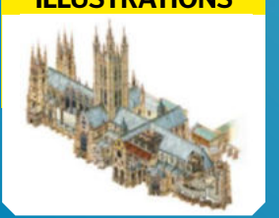	

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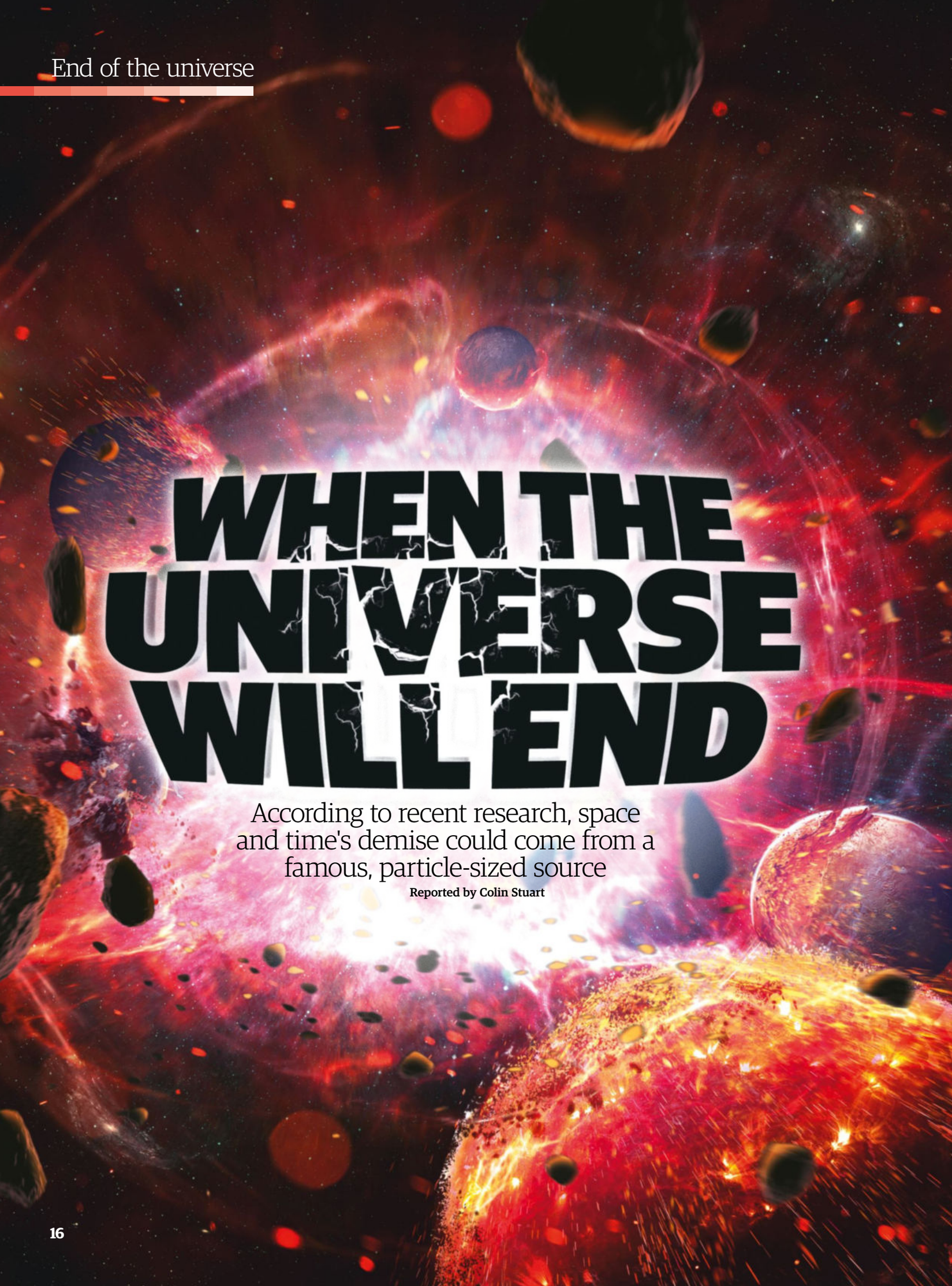


WHEN THE UNIVERSE WILL END

According to recent research, space and time's demise could come from a famous, particle-sized source

Reported by Colin Stuart

There are many ways the world could end: a deadly asteroid impact, a global pandemic of some super-contagious bug, a president with an itchy trigger finger. But what about the cosmos as a whole? Is there anything powerful enough to shatter the entire universe?

The ultimate fate of the universe has been a hot topic among astronomers for decades. Initially they contemplated a Big Crunch – effectively a Big Bang in reverse. If the universe contains enough material then, eventually, its collective gravity would overturn the outwards expansion from its creation and it would start to shrink back down. That would ultimately lead to a calamitous collision to end the universe in fire and fury. Thankfully that picture is now more than a little out of favour, thanks to a discovery made 20 years ago.

In 1998, and thanks to data from NASA's fleet of space telescopes, two teams of astronomers independently discovered something remarkable: the expansion of the universe isn't slowing down – it's speeding up. The explanation is that there is some invisible entity lurking out there in the shadows called dark energy. It would act as a sort

Peter Higgs predicted the existence of the boson that now bears his name in the 1960s

of anti-gravity, pushing galaxies apart at an ever-increasing pace. The more space between galaxies the more their gravitational attraction wanes, meaning dark energy dominates even more. It's a viscous cycle that could well tear the universe apart. Eventually space will stretch so much that entire solar systems would be ripped to shreds. Gaining even more traction, dark energy will even tear atoms and atomic nuclei apart until there is no longer any biology and chemistry in the cosmos. No stars and no life. This event – known as 'The Big Rip' – will leave the universe a splintered husk of its former self. According to research - including that conducted by teams at NASA - it could happen in as little as 22 billion years from now.

Despite the 2011 awarding of the Physics Nobel prize for its discovery, astronomers still know so little about dark energy and what it might be made of. This has led some researchers to claim it is just an illusion, the result of us applying the laws of physics beyond their usefulness. A figment of our collective imagination. Others have been looking into alternative culprits for the cosmos' ultimate destruction. According to particle physicists there is another contender we should add to the list of potential harbingers of doom: the Higgs boson.

Sometimes known as 'the God particle', it was famously discovered by researchers using the Large Hadron Collider (LHC) at CERN, Geneva, in 2012. It was first predicted to exist in 1964 by scientists including Peter Higgs, who now lends the particle his name. It was the missing piece in a sub-atomic jigsaw puzzle known as the Standard Model. Think of the Standard Model as a cookbook for the cosmos, containing the ingredients and recipes needed to make everything in the universe we see around us, from stars and galaxies to planets and people. The Higgs was seen as the Standard Model's crowning glory, a resounding success for the ingenuity of particle physicists, but it could also be the end of us all.

The particle, along with the associated Higgs field, is what gives all other particles in the universe mass. Imagine the Higgs field as an all-pervading cosmic ocean. A particle's mass is the result of how much it gets bogged down in this ocean. Particles capable of zipping through it like agile fish are incredibly light, but those that find the Higgs field like swimming through treacle are much more massive. However, the mass of the Higgs itself is capable of changing. If it ever did it would alter the strength of the Higgs field and fundamentally change everything else in the universe to boot,

"The Higgs was seen as the Standard Model's crowning glory, but it could also be the end of us all"

The energy emitted by primordial black holes could cause the Higgs to change energy states

including the masses of sub-atomic particles like the electron. "Chemistry relies on these masses being what they are," says Anders Johan Andreassen from Harvard University. If they change? "Life in that sort of universe wouldn't be sustainable," he says.

To understand how the Higgs might one day change its mass, it helps to picture two valleys either side of a central mountain. One valley sits at a higher altitude than its neighbour. According to measurements made at the LHC, the Higgs boson currently resides in this upper valley. Thankfully, the mountain – or potential barrier – blocking access to the lower valley is a high one. However, should the Higgs ever make its way down to the valley below it would then exist in a lower energy state than it is now, meaning the new Higgs field would contain a lot more energy. According to Andreassen, at least 100 trillion times more. This would fundamentally alter the way particles are able to move through it and radically change their masses. Such a change would lead to a burst of energy tearing across the universe at the speed of light, like an enormous cosmic tidal wave destroying everything it its path. The universe would be extinguished and we'd never see it coming.

What could make the Higgs jump down to the lower valley? The answer is simple probability. There's a rule in physics called the Heisenberg Uncertainty Principle which says that you cannot ever simultaneously know a particle's

Dark energy and dark matter

In recent decades evidence has grown for the presence of two mysterious entities in the universe

Made of matter

As its name suggests, dark matter is commonly thought to consist of a series of invisible particles. Dark energy, on the other hand, is not thought to consist of particles.

Getting experimental

There are lots of experiments all around the world trying to snare a dark matter particle as it arrives at the Earth. There are no dark energy detectors.

Outwards vs inwards

The presence of dark matter adds extra gravity that helps glue galaxies and clusters of galaxies together. In contrast dark energy has an anti-gravitational effect, pushing galaxies apart.

Extra strength

Dark energy is currently dominating dark matter because the rate at which the universe is expanding appears to be accelerating. That's despite dark matter's natural inclination to clump together.

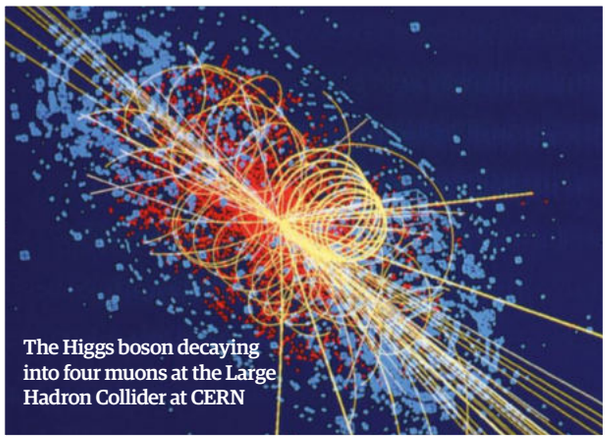
How much?

Dark energy dominates the total energy/mass budget of the universe. It is thought to make up 68 per cent, with dark matter contributing 27 per cent. The remaining five per cent is normal matter.

Old vs new

The first hints of dark matter date back to the 1930s. Dark energy, on the other hand, only became apparent in 1998 when astronomers accurately measured the expansion rate of space.

A 2016 study suggested that universe was expanding 5 to 9 per cent faster than previously thought



The Higgs boson decaying into four muons at the Large Hadron Collider at CERN

exact momentum and position. There's always some uncertainty. It means you can only ever say where a particle is statistically most likely to be. There is a tiny probability that a Higgs boson somewhere in the universe may one day suddenly and spontaneously find itself on the other side of the mountain. The universe is a big place with a dizzying number of bosons that could do just that.

Andreassen and his colleagues have been working to calculate exactly when this might happen. According to their work – the most accurate estimation ever made – it is so unlikely that we might have to wait 10^{139} years for it to occur. That's one followed by 139 zeroes! Andreassen stresses just how long this is. "If you counted every atom in the universe, at the rate of one every 14 billion years – roughly the current age of the universe – you could count all the atoms in the universe and still that amount of time wouldn't have elapsed," he says. In short, it's not something to lose sleep over. They are at least 95 per cent sure that the universe will last another 10^{58} years. Optimistically it could be as long as 10^{549} years.

It's worth saying that estimates like these are based solely on the Standard Model. Despite all its successes, it's a theory with some serious problems. It can't, for example, explain why the universe contains more matter than antimatter. Nor can it account for why tiny particles called neutrinos have a miniscule mass and can shapeshift between three different varieties. It completely omits gravity. The

"The Standard Model is very well tested, but these estimates are pushing it to its limit" **Ruth Gregory**

Astronomers have used Type Ia supernovae like this one to infer the presence of dark energy

How could the universe end?

There is a wide range of possibilities for the ultimate fate of the cosmos

Big Crunch

NO

This is the idea that the universe will come crashing back together in a reversal of the Big Bang. For that to happen there would have to be enough stuff in the universe – a critical mass density – in order to overturn the current expansion. There isn't thought to be enough matter for that to happen. The fact that the expansion of the universe currently seems to be accelerating makes it even more unlikely.

Big Bounce

NO

This is a close relation of the Big Crunch idea. Once a universe has contracted back into a vanishingly small point it might 'bounce' into another Big Bang. Such a scenario is a part of a family of theories known as cyclic universes. Our universe could be the result of such a series of events, or the first universe with the initial bounce yet to occur. It fell out of favour in the 1980s with the advent of a theory called cosmic inflation.

The Higgs could be kicked over the mountain by the Hawking radiation predicted by Stephen Hawking

weakest of nature's four fundamental forces stubbornly refuses to be brought into the fray. Dark energy is also not included.

"The Standard Model is very well tested, but these estimations are pushing it to its limit," says Ruth Gregory, a cosmologist at the University of Durham. "There might be new physics beyond the Standard Model that could come in and completely lift the lower valley up," she says. If that's the case, there'd be no lower valley for the Higgs to transition into and we'd all be safe. "It would remove this danger," Gregory says. "But at the moment we just don't know."

Gregory's own research has been looking into how black holes might change the picture. In particular she's been investigating the impact of primordial black holes – those thought to have formed in the early universe shortly after the Big Bang. "They change the calculation radically," she says. "It makes it a lot more probable." Stephen Hawking calculated that all black holes have a temperature – they radiate energy into space. The smaller the black hole, the more energy – or Hawking radiation – they emit. So these tiny primordial black holes can emit quite a lot of energy. According to Gregory's calculations, by the time they weigh just a ton they're producing so much energy that they might be able to give a Higgs boson enough of kick to boost it over the mountain and into the valley below.

"Accelerating expansion means distant parts of the cosmos are being carried ever farther from us"

Big Rip

IS IT LIKELY? • IS IT LIKELY? • YES

Astronomers believe the expansion of our universe started speeding up again a few billion years ago after initially slowing down as the energy from the Big Bang petered out. This is counter-intuitive, as gravity should continue to apply the brakes, so astronomers invoke another player in the game: dark energy.

It could continue to speed up the universe until even the space between atoms irrevocably stretches. The cosmos would be ripped to shreds in as little as 22 billion years.

Big Freeze/heat death

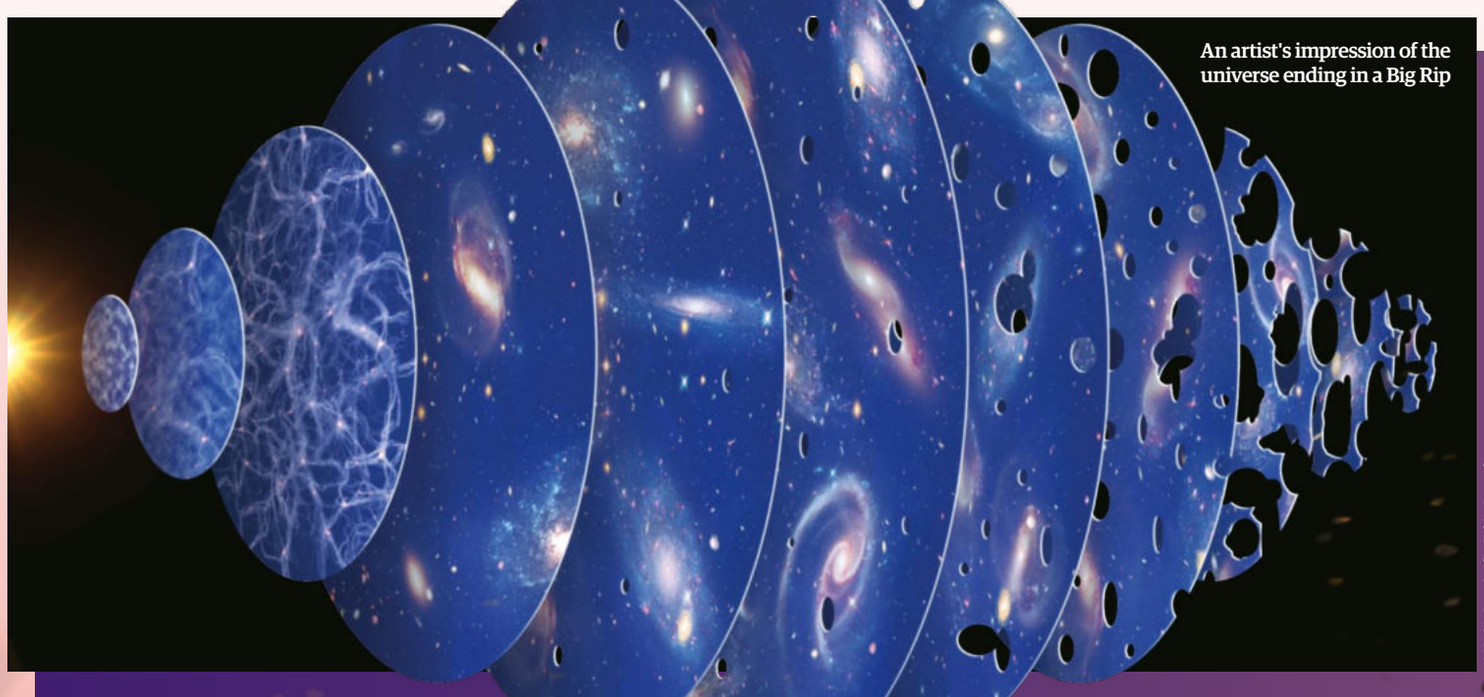
IS IT LIKELY? • IS IT LIKELY? • NO

If the universe continues to expand at a steady rate then there will come a time when everything becomes so separated that there won't be enough local energy for anything interesting to happen. The universe will continue to cool until it is impossible to create any order out of the growing disorder. It's a very old idea dating back to at least the 1850s and the work of British physicist Lord Kelvin (William Thomson).

Higgs bubble

IS IT LIKELY? • IS IT LIKELY? • MAYBE

The Higgs boson currently exists in a state that's the equivalent of a high valley adjacent to a mountain with a lower valley on the other side. If it ever found itself in the lower valley – either by chance, or by receiving a kick from a primordial black hole – it would change the mass of all particles and render the current chemistry of life impossible. Statistically it's unlikely to happen for 10^{139} years, though.



An artist's impression of the universe ending in a Big Rip

The standard model

Our very best picture of the particles that build the cosmos

The Higgs boson was the crowning achievement of the Standard Model and its decay into a lower energy state could destroy space-time. But, new physics beyond the Standard Model could make us question what will really happen at the end of the universe.

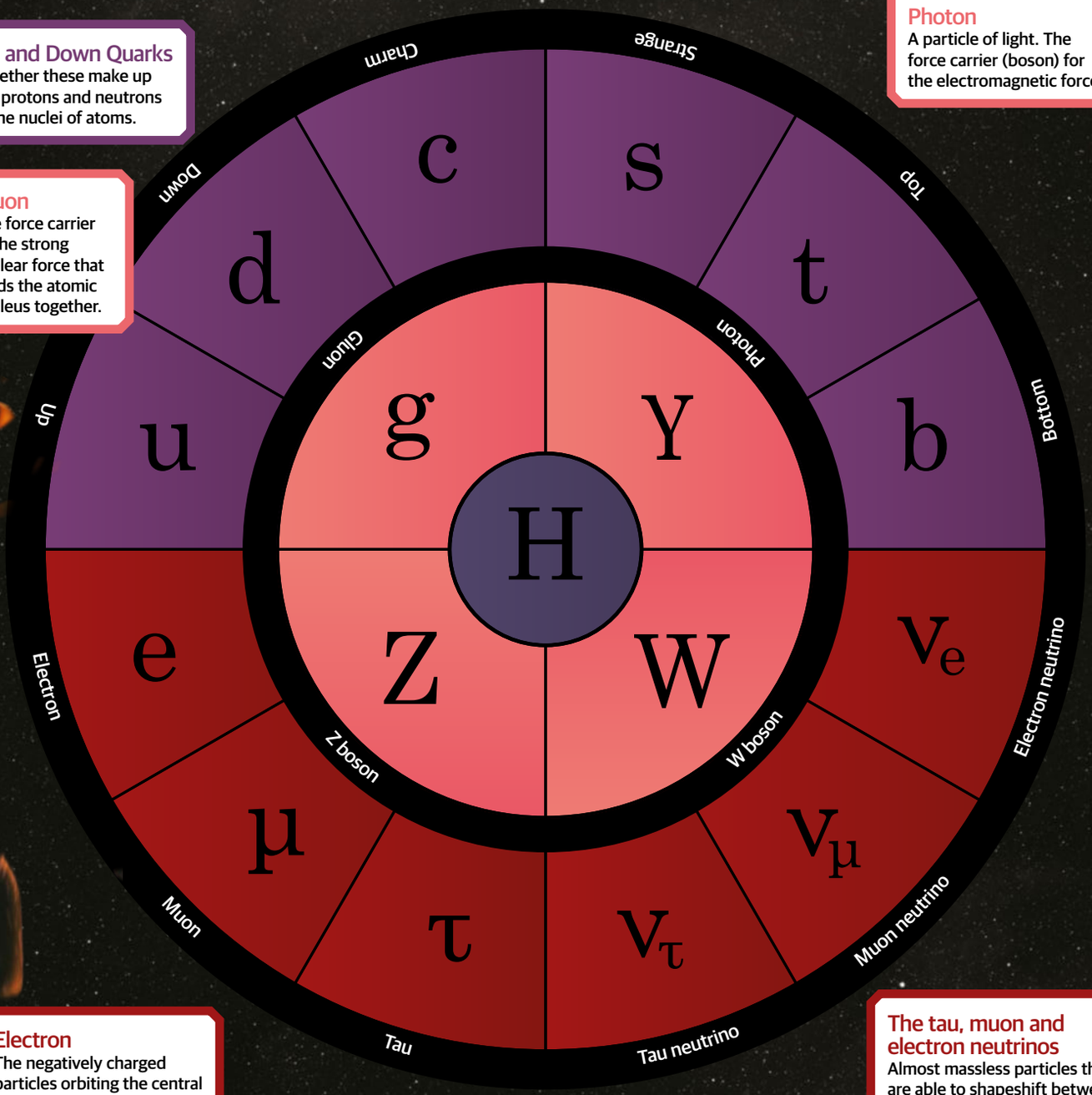
Higgs boson
The particle responsible for giving every other particle mass. Discovered at the LHC in 2012.

Charm, Strange, Top and Bottom Quarks
These are often found in particles consisting of matter-antimatter pairs known as mesons.

Photon
A particle of light. The force carrier (boson) for the electromagnetic force.

Up and Down Quarks
Together these make up the protons and neutrons in the nuclei of atoms.

Gluon
The force carrier of the strong nuclear force that binds the atomic nucleus together.



Electron
The negatively charged particles orbiting the central nucleus in a normal atom.

The tau, muon and electron neutrinos
Almost massless particles that are able to shapeshift between these three varieties.

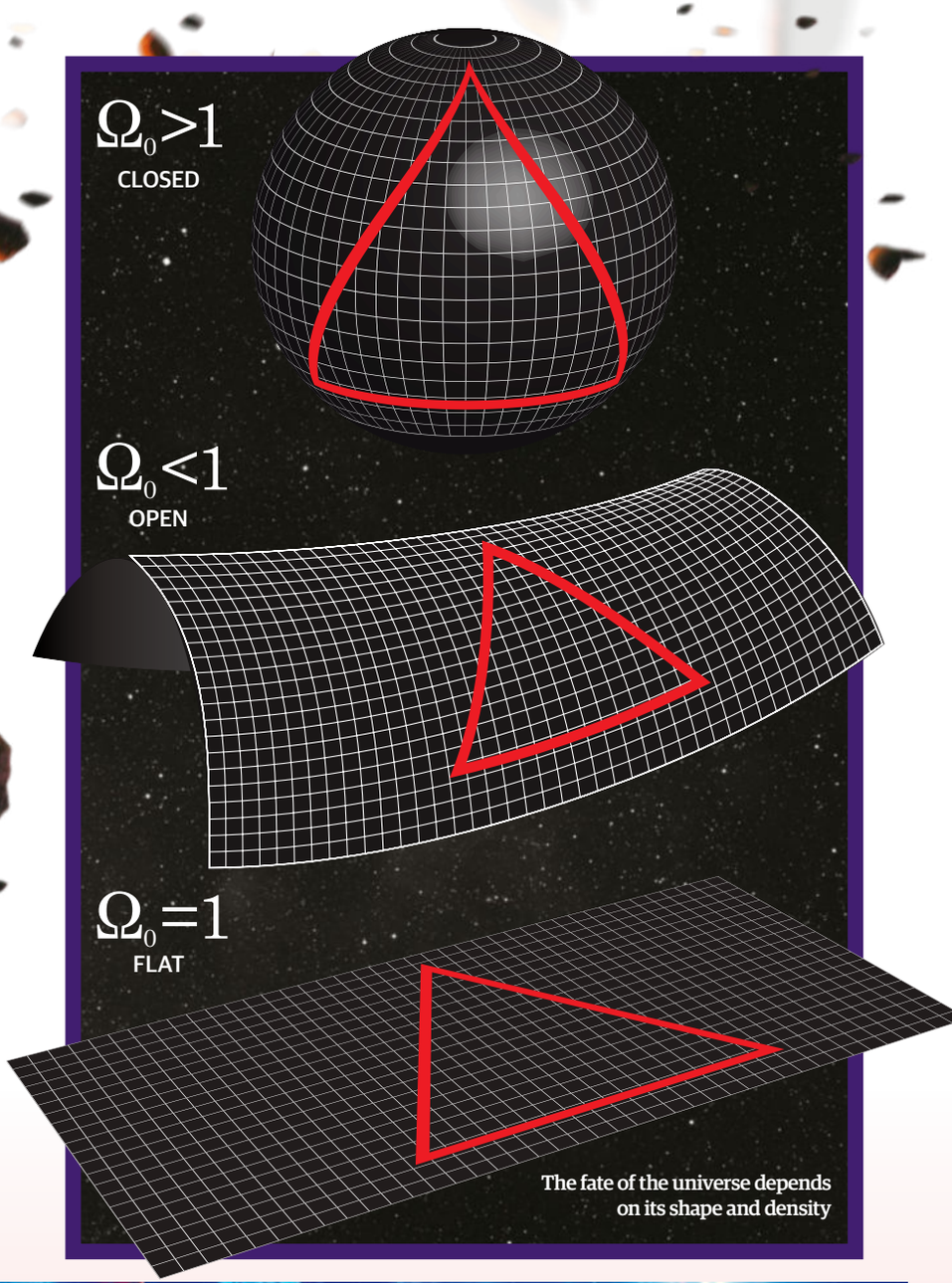
Tau and muon
Charged elementary particles similar to the electron but with a greater mass.

W and Z
The bosons for the weak nuclear force that plays an important role in radioactive decay.

The sobering news is that these primordial black holes started life weighing around a billion tons and so, by now, nearly 14 billion years later, some will have radiated away so much energy that they are approaching the one ton lethal threshold. "It all depends on how many primordial black holes actually formed," Gregory says. If they were rare, any dangerous one is likely beyond the limits of the observable universe and therefore it doesn't pose a threat to us. But if there were more then we might be in trouble. "There's not a consensus of opinion on precisely what the population is," she says. It seems like it is important to find out. One way that might be possible is to build gravitational wave detectors in space to pick up the ripples these diminutive black holes create as they collide.

If primordial black holes shorten the odds of this particular catastrophe, then dark energy might lengthen them. If the expansion rate of the universe really is accelerating then that means distant parts of the cosmos are being carried ever farther from us. Dark energy is effectively diluting the universe, meaning over time there should be both fewer Higgs bosons and primordial black holes to trouble us. The sting in the tail is if that's true the Big Rip will get us much sooner than a cascading Higgs.

Why bother with this line of research? After all, we would receive no warning of impending doom and there would be little we could do about it even if we could. Well, there are potentially valuable lessons we can learn about the nature of the universe. It could even lead to breakthrough discoveries in the search for physics beyond the Standard Model, particularly when it comes to dark matter – the invisible glue thought to bind galaxies and galaxy clusters together. Any theory for what dark matter might be made of should also describe how it interacts with the Higgs and how that would affect the chances of it jumping down into the lower valley. "It turns out that we're right on the edge between a stable universe and an unstable universe," explains Fermi National Accelerator Laboratory physicist Joseph Lykken. "Eventually it could just go boom."



The fate of the universe depends on its shape and density

Space and time is pulled apart in this artist's impression - but is that how the cosmos will meet its end?

Gregory H. Johnson

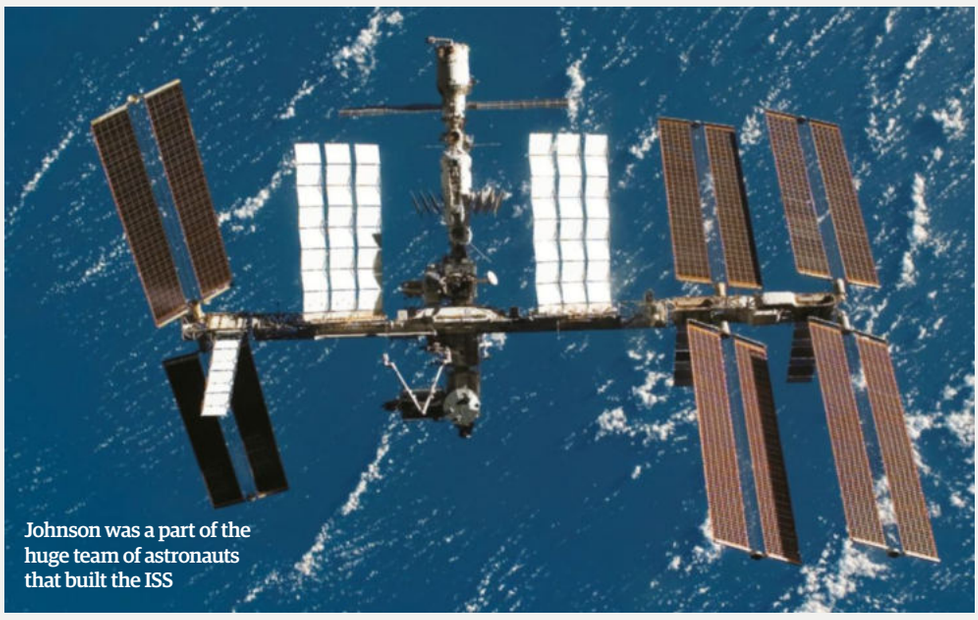
The former NASA astronaut reveals how he came to help build the International Space Station and what he thinks is best for the future of human space exploration

What made you want to become an astronaut?
My original motivation was the first lunar landing, when I was seven years old. At that time it was a dream, and I didn't really think it would be possible. This was until the early 1990s, when I finally had some touchpoints with astronauts, and in particular Charlie Bolden, who was then a pilot talking all around the country about the space programme and Space Station Freedom. So, in 1998, I was very surprised and thrilled to be selected as an astronaut, because I didn't think it would ever happen.

You started your NASA astronaut training in 1998, but didn't go on your first mission until almost ten years later. What kept you motivated?
The honeymoon motivation lasted for several years and yes, we knew there was a backlog of astronauts, and they weren't flying many rookies on the flights, maybe one or two. I had an office mate and his name was Stan Love, or Dr Love [laughs], and he extrapolated, based on the flight rate and how many rookies were going on each flight, that our first flight would be around 2016 or so. Of course that didn't turn out to be true. We had people in my class flying right after the return to flight in early 2006.

It is true that it [NASA] had a – for lack of a better term – glut of astronauts in 1996 and 1998. There were 44 astronauts selected in 1996 and there were 31 selected in 1998. The 1996 class was called the 'sardines', because it [NASA] packed them in, and the 1998 class – our class – was called the 'penguins' after the birds that would never fly. Between the two classes we had 75 new astronauts within a two-year time period. So there was quite a backlog on the books of people in the pipeline waiting to fly in space.

> "We were all trying to stick together, figure out what happened, get the shuttles flying again and help fix the problems"



Johnson was a part of the huge team of astronauts that built the ISS

But the promise of many more shuttle flights per year was the reason they chose so many astronauts within a short period, because we were just starting to assemble the International Space Station [ISS]. I don't know the original plan for how many flights were dedicated to it, but there must have been about 50. So if you do the maths, you realise you need a lot of people to do that, especially if you're trying to fly six or eight times a year. We didn't get that flight rate very often. I think there might have been one or two years that we executed this many flights, and that was partly to do with the Columbia accident that happened right in the middle of that ten-year span. We [the class of 1998 pilots] starting flying into space in 2006, and a few didn't fly until 2009 or 2010. I was certainly in the back half of the group that had an opportunity to fly in space.

I was really motivated throughout the initial astronaut candidate training in the first couple of years. During the next few years I was a 'cape crusader' [crew support in FL], one of the astronaut pilots who flew out to Cape Canaveral in Florida from Houston [Texas] often to help support the launches and the landings. Sometimes I'd end up in California for landings, but during that period of time I was really involved and focused on those missions. Although I wasn't flying those missions, I was deeply engaged with those missions.

And then the Columbia accident happened [turn to page 72]. For over two years we didn't fly shuttles at all, but following the investigations we had a really good flight rate and many of my classmates were starting to get to fly. So my motivation stayed strong due to different factors, but everyone knew what they had signed up for. Those nine-and-a-half years, I'd do all over again, but it was really a long wait.

What were you doing during the time after the Columbia accident?
Here we had a different motivation. We were all trying to stick together, figure out what happened, get the shuttles flying again and help fix the

INTERVIEW BIO

Gregory H. Johnson

Gregory Harold "Box" Johnson is a retired colonel of the United States Air Force, but is best known for his two spaceflights as a NASA astronaut. He flew as a pilot on missions STS-123 and STS-134, both aboard Space Shuttle Endeavour, in March 2008 and May 2011 respectively.

These missions were of the many that made up the hugely successful Space Shuttle program, which slowly built the International Space Station. Johnson has recently joined the Finnish-based organisation Space Nation, which wants to make space exploration more public.

Johnson was a pilot of both Space Shuttle missions, STS-123 and STS-134

problems that were in the shuttle system.

I would say that the space shuttle accidents, although they were terrible, each time we had an accident, we as an agency and as a country and as a space community worldwide learned great things from those accidents. So the Columbia accident was no exception. We didn't just learn about thermal protection systems, which ultimately led to us finding out what breached the thermal protection system that took Columbia out, but we looked at all different parts of the shuttle from launch all the way through to landing. The shuttle, when it returned to flight, was probably the safest shuttle we ever had.

Did you think you'd only complete the one flight?
I didn't think I'd get two flights. I thought at the time, in the early 2000s, that I'd only get one flight. Luckily they added a few more shuttle flights to the manifest at the very end [of the shuttle program] and I slipped into that second flight and I was really excited to have that second flight as well. I was amazed actually, to get a second flight.

"Luckily they added a few more shuttle flights to the manifest and I slipped into that second flight. I was amazed actually, to get a second flight"

How do you feel looking back on the space shuttle missions that built the ISS? Especially with how far the station has come along since.
I look back on it with great pride for our country [the United States], and for the entire world. I was so happy to be a part of that enterprise. It took over a dozen years to assemble the ISS, one flight at a time. The entire astronaut corps and many factions of NASA, as well as the other space agencies around the world, were involved in this amazing engineering achievement. So I'm very happy as I look at the work NASA and the collaboration did, and the entire space station program.

It's further underscored by my involvement in the ISS' US National Laboratory, which followed in the subsequent five years after I left NASA in 2013. So I look back on that with great satisfaction and happiness, and I'm pleased to have been a part of it.

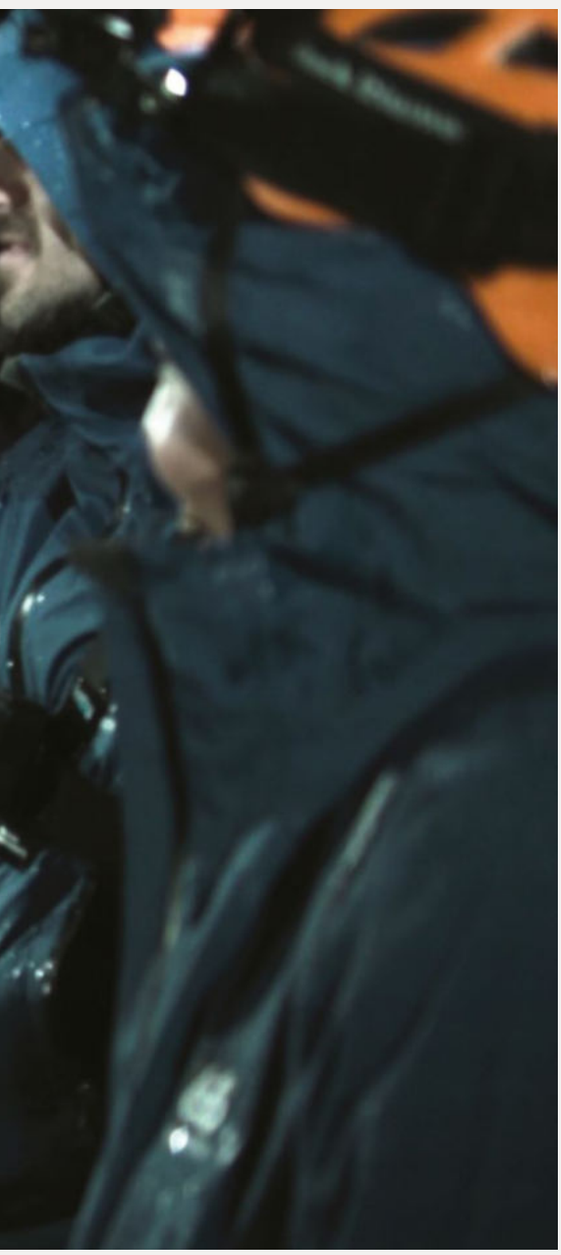
During your time in space, did you feel any significant changes to your body?
It's funny; some of the changes were a little insidious and some were very immediate. Obviously when we get into continuous microgravity, which happens right after main engine cut off at eight-and-a-half minutes after launch, I think I was laughing [at that time] more than anything else, as it was so different than standing on the ground. We did practice zero gravity in 30-second intervals in the

Space Nation aim to make space more accessible for everyone

'Vomit Comet'. This is an aeroplane that we trained in to get little segments in microgravity. But once you're in continuous microgravity for a few minutes, it is really different. Things were floating, as if it was under a different set of rules. It's kind of like walking into an *Alice in Wonderland* world, as the rules were so different.

We also had different physiological changes that happened fairly immediately. You start feeling a little bit of fullness in your head. Some people get nauseated immediately; with me it was kind of a bit more insidious. Most of us had it in just that period, at least the first day or two, and some never actually got over it. This is because your body is just confused. Your vestibular system is accustomed to having fluids settle in the semicircular canals [in your ears], but it just never does, as the fluids just float around in there. So the nausea is one that can be pretty immediate.

I'm curious as to how long it took me to grow about five centimetres taller. But we did measure ourselves several days into the flight and every one of us had grown a few centimetres. I grew as much as five centimetres. Without gravity continuously pulling through our spines, our bodies get longer.



Johnson worked extensively on finding out the cause of the Columbia disaster

There are other effects also, like vision can shift. Some astronauts experienced vision shifts by up to three dioptres, I understand. My vision actually got better, interestingly enough. In fact, I didn't need to wear the glasses I brought with me. But then again, when I came back to the Earth my eyes popped back.

So there are a lot of changes to the human body. Although there are changes, our bodies are really adaptable. We get used to some of those changes very quickly.

How long was the recovery period when you got back to Earth?

A couple of days. I mean, with me, I had relatively short flights. My flights were about 16 days each. The recovery period compares to the amount of time you spent in space, so astronauts that have had six months to a year in space had a much longer recovery period.

Our bones degrade about two per cent per month if we're not doing intense exercise in space, and I didn't do a lot of anaerobic [exercise]. I did quite a bit of aerobic exercise with the bicycle on the shuttle.

About four hours into my return, I had finally met my family for the first time and they handed me a Diet Coke. So I was drinking the Diet Coke with my right hand and my ten-year-old daughter came up and I was hugging her with my left arm. At that time, the NASA administrator [Michael Griffin], walks up to me to shake my hand and congratulate me for my first shuttle flight.

Normally I would do a hand off with the Diet Coke to my left side - but instead of handing my drink off, I just released it, because of course in space it would just float. So I released it, and just as I reached my hand out to the NASA administrator, my Diet Coke [hit the floor and] splashed all over his shoes!

Space Shuttle Endeavour can be seen successfully docked onto the ISS

Johnson floats through a hatch on the International Space Station

How do you feel about the American government's plans to end public funding for the ISS by 2025?

I don't think those plans are quite as strong as stated. I think that there is a desire for the public funding of the space station to be handed off to commercial entities, so then it would allow more money for NASA to get out of low-Earth orbit to the Moon or Mars. That's the hope. But I feel fairly certain that it's a desire to decrease the public funding, and it's not just going to drop dead in the water.

We've learned so many times – we've learned from the Apollo program and we've learned from the Space Shuttle program – that just ending programmes is problematic. It is better to transition out of programmes as the maturity of the programme evolves. We transition naturally as opposed to forcing its transition.

We're making the transition now, and it has been transitioning over the last five years. A lot of new commercial activity has shown up on the space station and there are so many companies now that are thinking about how they can commercialise space, such as Bigelow [Aerospace], Axiom Space, NanoRacks and SpaceX.

But as far as forcing it by a particular date, I don't think that makes a lot of sense. We'll see how that goes. I believe there's a lot of debate in [Washington] DC on this issue, but I'm hoping we do the right thing instead of driving it in a direction that may not be ready for the transition yet.

Can you please tell us about Space Nation and what drew you towards it?

Space Nation is an interesting model, and is thinking differently about how we put humans in space. Most of the astronauts and cosmonauts have mainly come from the US and Russia, but they have also come from other countries as well. However, there are some countries, maybe 150 or so, who haven't had anybody who has even had the opportunity to fly in space.

Space Nation is trying to make it open for anyone, and its model is to bring the space programme to every living room, classroom and every household around the world, where people can get involved, engaged and ultimately compete for the opportunity for space flight. It is a very interesting concept.

That's what attracted me to it, because it's thinking outside of the box and it's thinking forward. It's not tied to any particular traditional nation on the Earth, but all of the people around the Earth who are space-minded, and those thinking about space as a nation are invited to join. There are no borders to the pool of people that can be engaged in this enterprise.

Ultimately, it's not just going to be government-funded people working in space; it's going to be everyone. The 'citizen astronaut' is going to be a real thing in the future, I don't know when, but Space Nation is leaning towards that idea.

So what do you think is the next step for Space Nation then?

It's doing a couple of things. One is it's building its infrastructure to create awareness and membership and involvement with more and more people around the world. There's going to be a competition that is going to fly someone to suborbital flight, I believe next year. After that happens, the hope is to get Space Nation astronauts up to low-Earth orbit and beyond. Crawl before you walk; walk before you run.

But it's a completely novel concept. It will be good for the Space Nation mission when commercial modules actually start showing up on the space station, for example whole modules [on board the ISS], and that is right around the corner. The Space Nation's next step will probably be suborbital, until there's a modular piece on the space station that can be used for completely non-government activities.

Do you think astronauts should be sent back to the Moon before going to Mars, or should astronauts cut out the lunar visit and go straight to Mars?

I think we should go back to the Moon for all the reasons that you read about. It is closer. We haven't been there in roughly 50 years and the people who went to the Moon have left the workforce. So I think we should go back to practising our techniques closer. We could figure these out on the Moon and then go to Mars.

If there was the opportunity to go to Mars, and you were in top physical condition, would you go to the Red Planet?

Well, that's a complicated question. If you're talking to just me, Greg Johnson, I'd do it in a heartbeat. But I have a lot more responsibilities now at age 56 here on the Earth then I had when I was younger. But my answer is, if you were talking to just me, yes, in a heartbeat. But I'd have to look at the entire picture before committing.

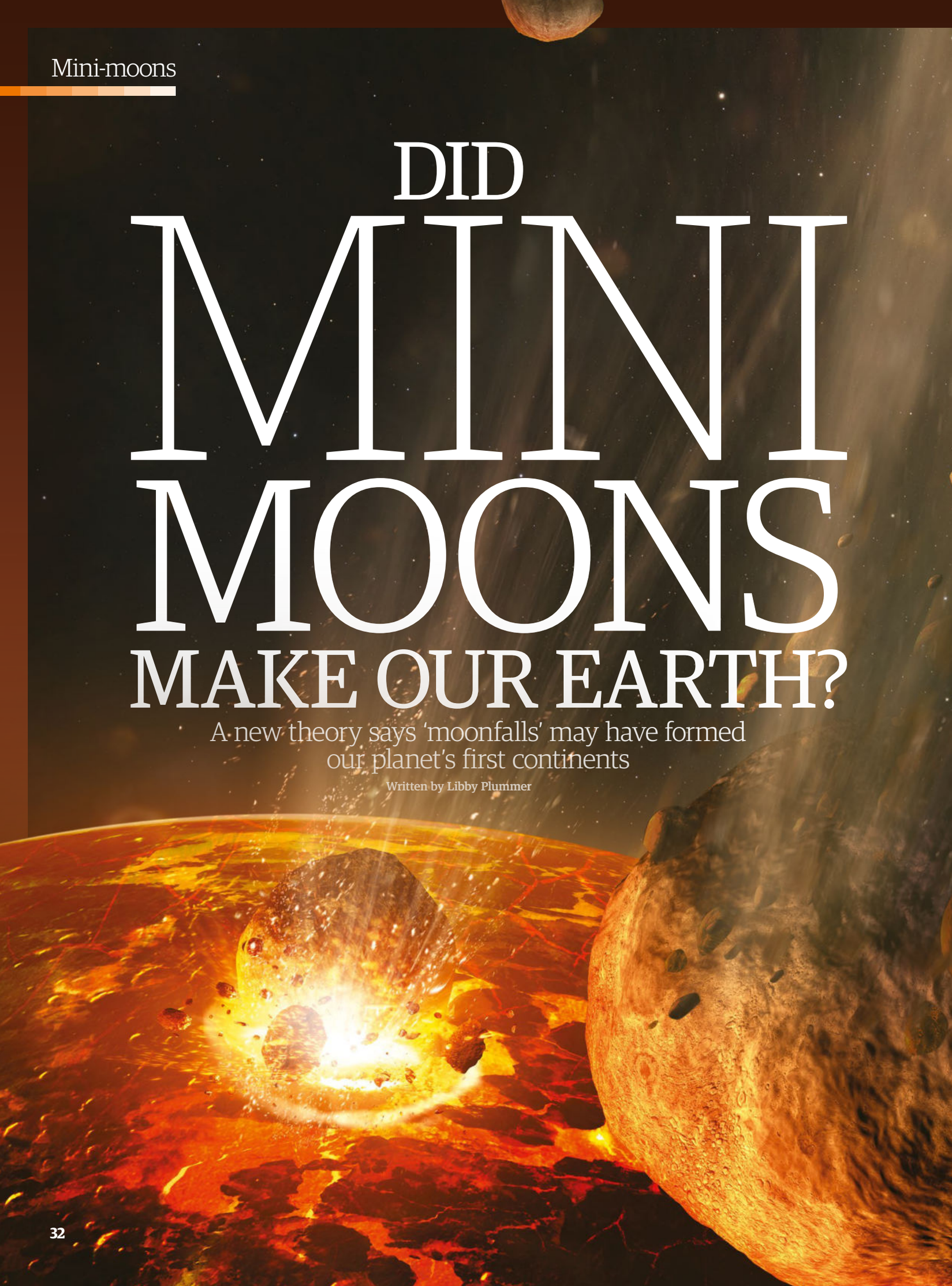
"It's not just going to be government-funded people working in space; it's going to be everyone. The 'citizen astronaut' is going to be a real thing in the future"

Johnson recently received an honorary Eagle Scout Award

DID MINI MOONS MAKE OUR EARTH?

A new theory says 'moonfalls' may have formed our planet's first continents

Written by Libby Plummer



Mini-moons may have battered Earth with debris in its formative years, shaping the young planet and maybe even building the first continent. That's the theory put forward by a new study which turns the 'giant-impact hypothesis' on its head.

In the well-established giant-impact theory, a Mars-sized rocky object called Theia smashed into what would become Earth around 100 million years after the Solar System was formed. The giant collision spewed debris up into space forming a disc of debris, some of which gradually came together to form our Moon.

This idea was initially put forward in 2012, and then four years later, researchers at the University of California, Los Angeles (UCLA) published new evidence to cement the theory. While it was previously thought that the collision, which took place around 4.5 billion years ago, was a powerful, angled side-swipe by the giant rock Theia, the new evidence confirmed it was likely to have been a violent, head-on smash. The team came to this conclusion after analysing seven rocks brought back to Earth by the Apollo 12, 15 and 17 lunar missions, along with six volcanic rocks from the Earth's mantle. A shared chemical signature in the oxygen atoms both in the Moon rocks and the Earth rocks made it likely that a head-on collision had occurred, the researchers concluded.

"Theia was thoroughly mixed into both the Earth and the Moon, and evenly dispersed between them," said Edward Young, UCLA professor and lead author of the study, speaking at the time of its publication. "This explains why we don't see a different signature of Theia in the Moon versus the Earth." The study explains that the alternative, a glancing side blow from Theia, would have meant that the vast majority of the Moon would have been formed from Theia, and that the Earth and Moon would have different chemical 'fingerprints'.

However, a series of recent studies argue that the Moon wasn't formed by a single collision alone, but rather a series of impacts. The latest research, which at the time of writing had been published online and has been accepted for publication in the *Monthly Notices of the Royal Astronomical Society*, suggests that multiple impacts on Earth would have blown debris back into orbit, which then came together to form our Moon, along with lots of smaller mini-moons or 'moonlets'. Complex movement between these moonlets would have slowly changed their orbits, gradually making them more elliptical. Many of them would then have crashed down on to the proto-Earth, battering the fledgling planet time after time. These 'moonfalls' would have caused a build-up of material in localised spots, leading to the formation of topographical features and potentially even the Earth's first continent. The researchers were able to demonstrate the hypothesis using a series of simulations. The study was based on smoothed-particle hydrodynamical (SPH) simulations, where a computer is used to reproduce processes such as star formation and meteor impacts.

This new theory was put forward as the researchers believe that the widely accepted idea of how the Moon was formed doesn't quite add up.

"The current [giant-impact] paradigm is intrinsically incomplete and disconnected from the wider picture of terrestrial planet formation in which the proto-Earth had experienced and grown though multiple planetary-scale impacts," co-author of the new study Hagai Perets from the Technion Israeli Institute of Technology explains to **All About Space**. "Consideration of only the last such impact in the current paradigm disregards the critical evolution taking place prior to – and possibly following – this event."

That's why the researchers investigated the new scenario in which Earth's Moon may be the result of a merger of lots of mini-moons, and where Earth's geophysical and geochemical make-up was altered by the multiple-impact evolution of the Moon.

"The current paradigm is challenged by several major difficulties, as mentioned in this and previous papers," says Perets. "Generally, the multiple-impact model we suggest naturally connects Earth's Moon formation with the global formation of the Solar System, and potentially constrains it. These issues and challenges call for a paradigm shift, and motivate the novel conceptual framework we propose. The current paper on Earth-Moon collisions is one piece in this new model, and we are working on several other implications, such as studying Moon-moon collisions."

The new theory builds on research published last year from Perets and a different inter-university team which challenges the most prevalent theory of how the Moon formed. It suggests that the Moon that we see is not Earth's first moon, but the latest in a series of rocky satellites, and that it was formed by a series of impacts rather than one big smash.

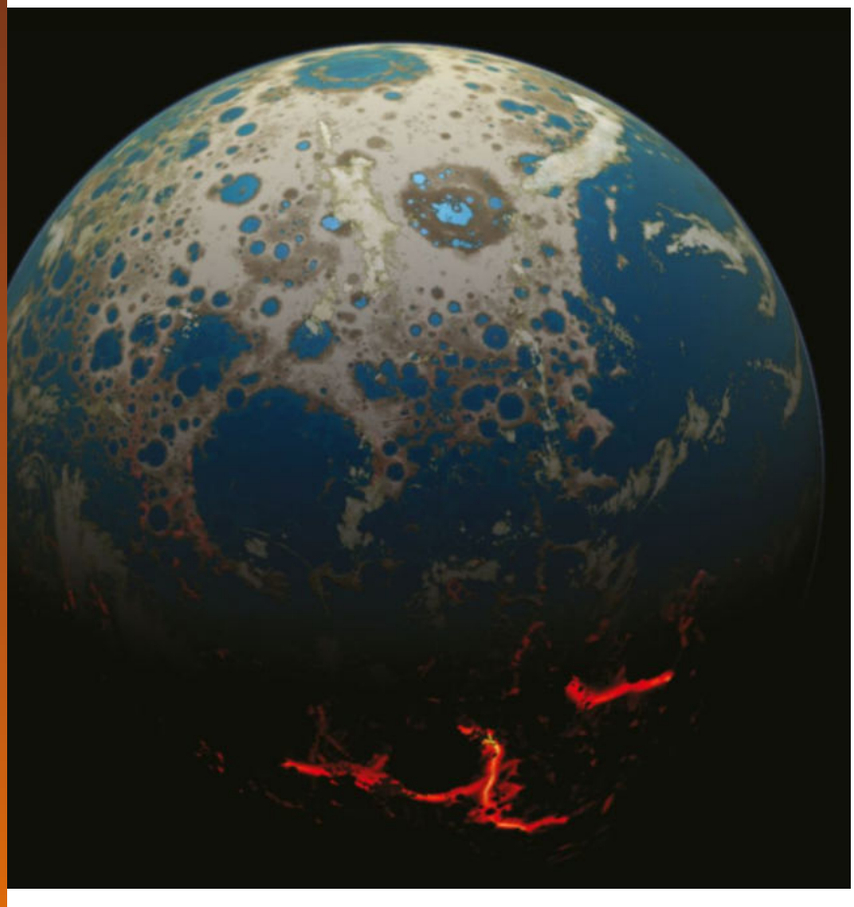
While the idea of one major collision is currently the accepted theory, the researchers behind the recent studies claim that this scenario requires very specific conditions, which are rare. They claim that the idea of a series of impacts is far more feasible.

"The multiple-impact theory is a more natural way to explain the formation of the Moon," Raluca Rufu from the Weizmann Institute of Science tells **All About Space**. "It does not require one single and specific impact, but rather incorporates all the possible impactors Earth experienced during the late accretion stage [when Earth was formed]. Each moonlet accretes from a different debris disc and eventually merges with previous existing moonlets at low velocities, where the mixing between the two components is not efficient. This can explain some of the observed lunar heterogeneities in the Moon's interior," said Rufu, lead author of the research study, published in *Nature Geoscience* last year.

The authors admit that there are limitations to the new multiple-impact hypothesis, largely that it is based on a limited dataset, making it harder to model possible collisions.

"In the current model we explore the implications of moonfalls on the Earth using simulations of the impacts themselves, making use of a hydrodynamical code," explains Perets. "We consider a grid of models for the initial properties of the impact [position of the impact, size of the impacting moon, rotation of the proto-Earth] motivated by the study of dynamics leading to the infalls. This is only one piece in the overall model of the multiple-impacts theory. The main limitations are in direct

> "The current [giant-impact] paradigm is intrinsically incomplete and disconnected from the wider picture of terrestrial planet formation" **Prof Hagai Perets**

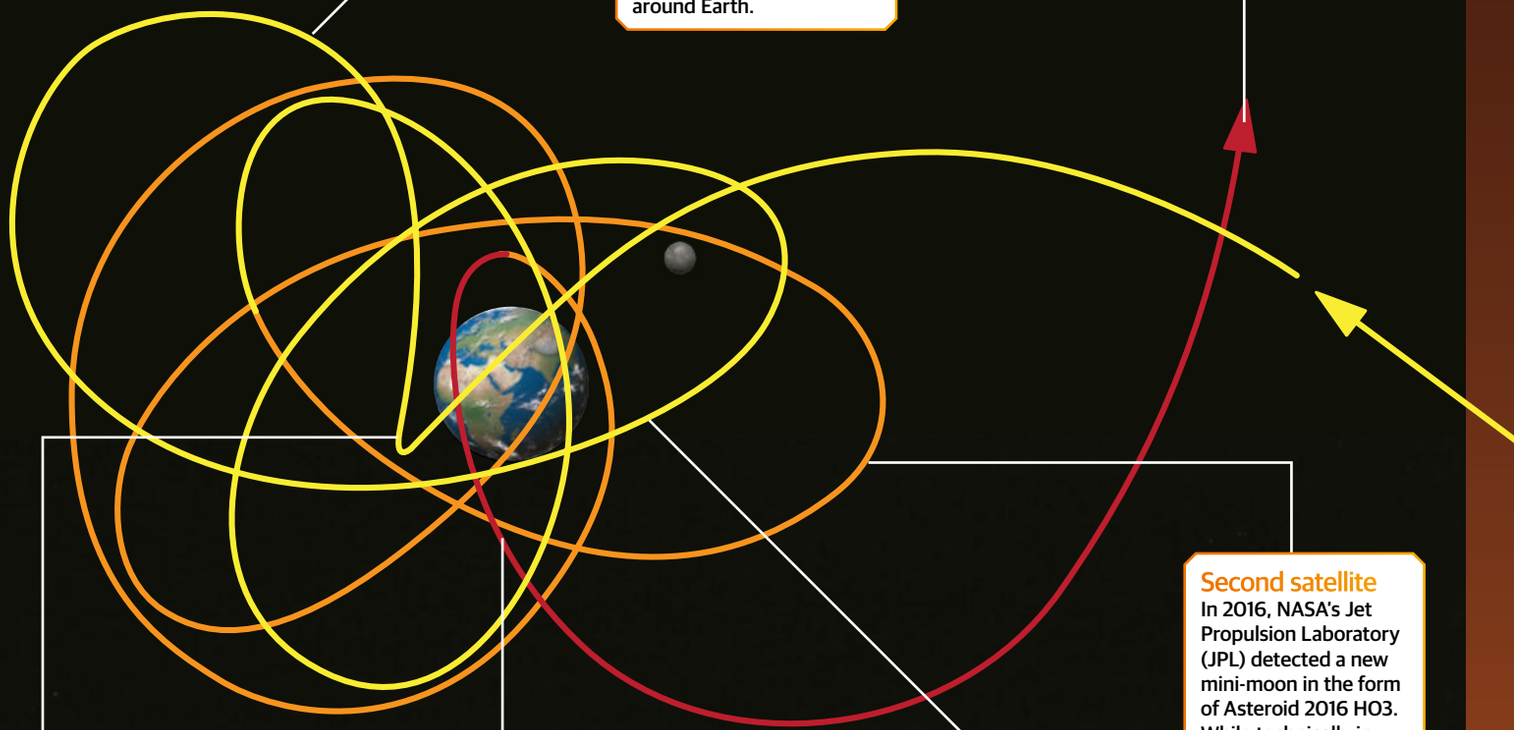


Left: Earth was battered by asteroids during its formation

Below: Falling mini-moons could be responsible for the formation of Earth's earliest continents

Earth's little moons

Our Solar System's planets have more than one moon - even our planet - on occasion



More than one moon

The Moon isn't our only satellite. Asteroids orbiting the Sun can temporarily become mini-moons following a complex path around Earth.

Temporary visitors

A typical mini-moon will orbit the Earth for around nine months, although some could stay in orbit for decades or more before being recaptured into orbit around the Sun.

Second satellite

In 2016, NASA's Jet Propulsion Laboratory (JPL) detected a new mini-moon in the form of Asteroid 2016 HO3. While technically in orbit around the Sun, the 'quasi-satellite' appears to circle Earth as well.

A complex journey

As they are tugged in different directions by the Earth, Moon and Sun, mini-moons follow complicated paths rather than neat elliptical orbits like the Moon.

A confirmed mini-moon

In 2006, the car-sized 'RH120' mini-moon was discovered. It orbited Earth for less than a year before returning to the Sun's orbit.

Tiny satellites

Their small size can make them hard to spot, but experts think there could be a large amount of undetected mini-moons around Earth.

This stunning image of the Earth was taken on the Apollo 8 mission while the astronauts were in lunar orbit

predictions that can still be observed today billions of years after the fact.

"The general limitation of any Moon model [both single- and multiple-impact models] is that we have only one system to check – we don't have statistics of many moons and their properties. The other limitation is that overall the phase space of possible collisions and impacts is very large, and it is therefore difficult to model any possible type of collision. We only run a grid sampling the huge phase space of possibilities. Nevertheless, there are clear trends that suggest we can generalise our results to a wide range of collisions, so this is not a main obstacle."

So, if the new mini-moons theory is correct and the first continents on Earth really were formed by moonfalls, how exactly would we go about proving this?

"The best evidence might be on the Moon," explains Perets. "For example, if we find that the composition on the far side of the Moon is significantly different than that found on the near side, it could be a clear signature of multiple moons making up the current Moon. That being said, finding a small difference, or not, would not exclude it. The Chinese are planning a mission to the far side of the Moon in the coming years, so hopefully we might have data on that sooner than we think."

The making of the Earth

The nebular hypothesis is the most widely accepted theory of how our planet formed, at roughly the same time as rest of our Solar System's worlds

A proto-planet is formed
4.6 billion years ago
Gravity caused the Solar System, then a cloud of gas and dust, to collapse in on itself, forming the Sun. Some of the remaining material accumulated to form the Earth's rocky core.

The giant-impact hypothesis
4.5 billion years ago
A Mars-sized rocky object known as Theia smashed into the proto-Earth, catapulting pieces of the young planet's mantle into space. Some of these pieces merged to form our Moon.

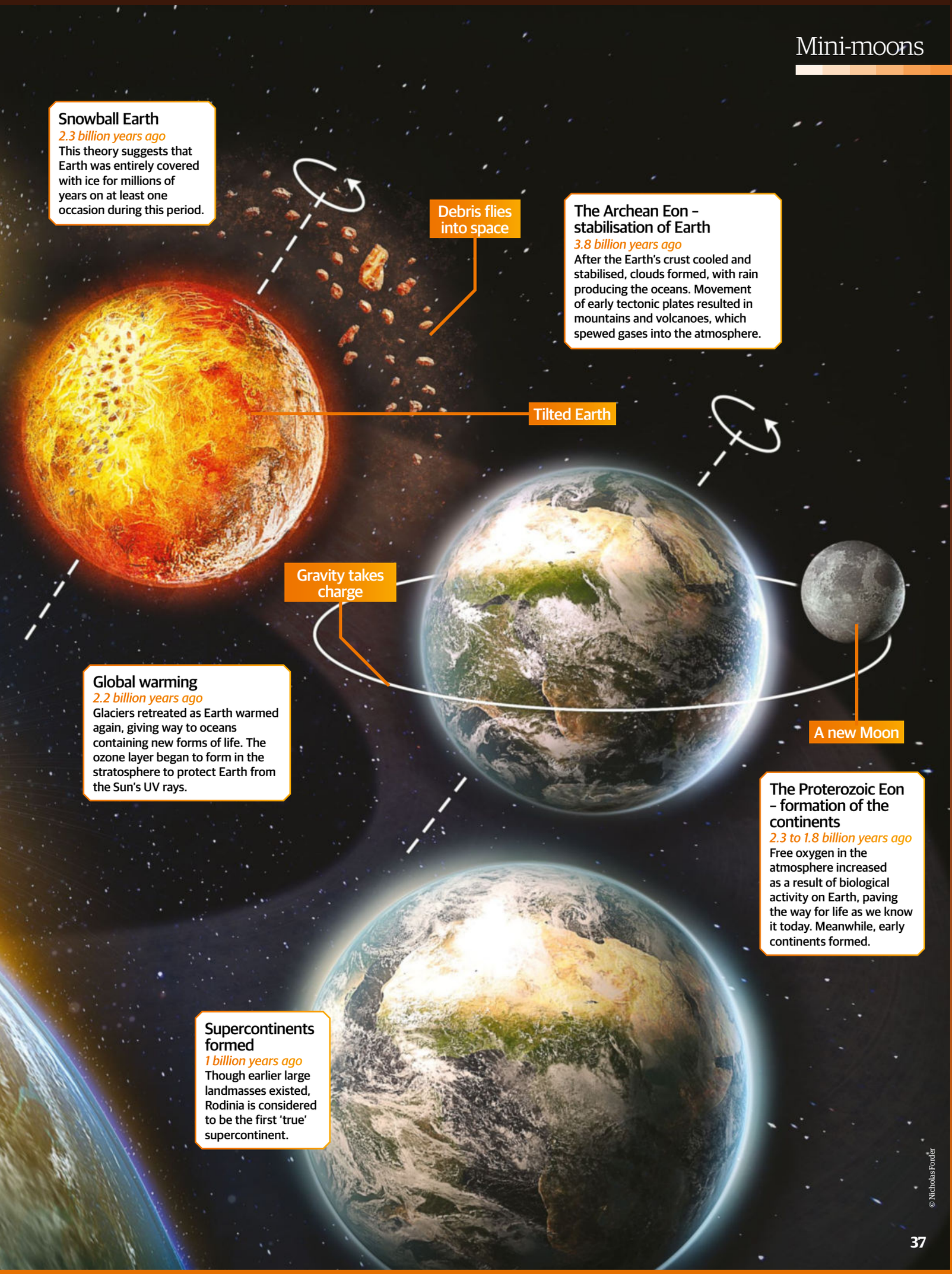
The Tertiary Period
65 million years ago
The bumping of tectonic plates lead to rocks being pushed upwards to form modern mountain ranges such as the Alps and Himalayas.

Pangaea formed
About 300 million years ago
The supercontinent that would eventually split apart to make Laurasia and Gondwana, which then went on to become the seven continents we know today.

Theia strikes Earth

A powerful impact

Meteorite collisions
4.5 to 3.8 billion years ago
Earth developed into a solid sphere after being bombarded by the remaining debris in the form of asteroids, meteors and comets, which likely deposited much of the Earth's water onto its surface.



In May, the China National Space Administration (CNSA) launched a relay satellite which paves the way for this historic mission to the far side of the Moon. The satellite will provide a way for an upcoming lunar rover to communicate with Earth. Because the Moon is tidally locked to Earth we only ever see its near side, which is where all of the Apollo lunar landings were made. If successful, China's Chang'e 4 robotic orbiter-lander-rover would be the first spacecraft to ever touch down on the Moon's far side. The mission is currently scheduled for launch in December 2018, so new insights on the Moon formation theory could possibly be gleaned as early as next year.

The idea of impacts leading to the formation of topographic features on planets' surfaces isn't new. The latter stages of planet formation are widely thought to be characterised by extremely violent, catastrophic collisions, and features such as mountains can be seen on planets throughout the Solar System. But some experts disagree that the falling mini-moons would have formed any such features on Earth.

As the Earth took around 100 million years to cool from molten magma into a solid sphere, it is questionable whether mini-moons falling during that time would have left any mark on the molten planet. However, the researchers argue that the moonlets would have struck Earth after much of the planet had solidified into a crust and that the impacts would have been gentle enough to remain on the surface, rather than smash through.

While not yet conclusive, the idea of multiple strikes on Earth producing a series of moonlets which then rained down on Earth is certainly a compelling alternative to the accepted theory. But why is it so important?

"The latter stages of accretion, named the giant-impact phase, set the final architecture of the Solar System, and the composition of the final planets and their satellites," explains Rufu. "Understanding the formation of the Moon can provide insights on the environment of the early Solar System and it may help us understand whether satellite formation in general is abundant or whether it requires unique impact conditions.

UCLA researchers Paul Warren, Edward Young and Issaku Kohl. Young is holding a sample of a rock from the Moon which backs up the giant-impact hypothesis

"Understanding the formation of the Moon can provide insights on the environment of the early Solar System and help us understand satellite formation" **Raluca Rufu**

"Moreover, due to its large size, the Moon stabilises Earth's tilt and provides a somewhat stable climate for life to evolve. If detecting exo-moons [satellites that orbit planets in other satellite systems] will be possible in the near future, then it may be more beneficial to look for life around planets with large satellites. Of course, this is somewhat speculative, as we know of only one planet that harbours life and it happens to have a large satellite."

A better understanding of the impacts that shaped the evolution of Earth could give us vital insights into how life-bearing planets form. In turn, this could help us track down potentially habitable planets in future, and maybe even ensure the endurance of the human race for generations to come. So, if the new theory is correct, mini-moons may well have shaped not only our past, but also our distant future.

A concept drawing of early Earth depicts it battered by falling debris in the forms of asteroids, meteors and comets

STUCK IN A MARTIAN STORM

NASA's Opportunity rover has been stuck in one of the thickest dust storms ever observed on Mars

The dust storms that arise on Mars aren't as disastrous as portrayed in the 2015 sci-fi blockbuster film *The Martian*, however, observations from NASA's Mars Reconnaissance Orbiter (MRO) have recently shown a dust storm grow in size over the period of a week and a half. This storm even caused NASA to suspend science operations for its Opportunity rover, which was caught up in the middle of it.

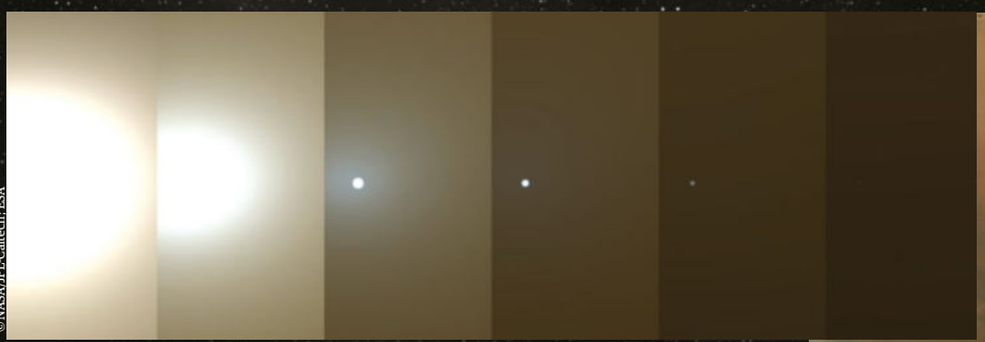
"This is the ideal storm for Mars science," says Jim Watzin, director of NASA's Mars Exploration Program at the agency's headquarters in Washington, United States. "We have a historic number of spacecraft operating at the Red Planet. Each offers a unique look at how dust storms form and behave – knowledge that will be essential for future robotic and human missions."

Mars is a harsh environment for humans, and one of the main reasons is because of its very thin atmosphere. Mars' atmosphere is less than one per cent of Earth's, and although this means the winds created aren't as strong as Earth's, sometimes a dust storm is created that can envelop the entire planet. These storms are thought to occur once every three to four Martian years, which is equivalent to six to eight Earth years.

This recent storm that has temporarily ceased Opportunity's operations at one point covered 35 million square kilometres (14 million square miles) of dry Martian land, which is a quarter of the whole planet. With an event this large, NASA fully intends to have a fine network of instruments in different spacecraft dedicated to carefully studying the storm. Another ground-based rover that has seen the effects is NASA's Curiosity. Currently residing in the Gale Crater, Curiosity has begun to detect an increase in the dust haze that blocks out sunlight. As Curiosity has a nuclear-powered battery, it doesn't face the same troubles as the solar-powered Opportunity.

NASA also has two other orbiters at Mars that are providing unique scientific observations; this duo consists of the 2001 Mars Odyssey and the Mars Atmosphere and Volatile Evolution (MAVEN) orbiters. Odyssey has a built-in infrared camera that can measure the dust levels on Mars, and MAVEN will watch any changes in the upper atmosphere and any loss of gas to space.

"Each observation of these large storms brings us closer to being able to model these events – and maybe someday being able to forecast them," says Richard Zurek, project scientist for the MRO. "That would be like forecasting El Niño events on Earth, or the severity of upcoming hurricane seasons." Although this storm presents an opportunity for Martian orbiters and rovers to analyse an extreme event, this comes at the risk of losing the Opportunity rover. As Opportunity runs primarily on solar-powered batteries, cutting off the sunlight could cause a huge problem. Fingers crossed that this long-standing rover lives to see another Martian day when the storm has subsided.



Dust storms on Mars can potentially cover the entire planet, depending upon their severity

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A Model Aircraft

THE RAF RED ARROWS HAWK

The British Aerospace Hawk is one of the most important British jets. Having first flown as the Hawker Siddeley Hawk in Surrey in 1974 the Hawk is still in production in the UK today and is sold to many different countries all over the world. The Hawk is considered a "low-cost" combat aircraft, in 2003 one would've reportedly cost you approximately £18 million!

Without doubt, the most famous of the 1000+ BAe Hawks produced are the aircraft which wear the distinctive colours of the Royal Air Force Aerobatic Team 'The Red Arrows', arguably the world's best and certainly the most famous aerobatic display team.

The Red Arrows have been performing their thrilling displays to audiences all over the world since 1965, fulfilling the role of Britain's most effective flying ambassadors wherever they appear. To join the Red Arrows display team candidates have to have completed a front line tour as a Royal Air Force pilot, have a minimum of 1500 flying hours and be assessed as "above average" in their current RAF flying role. A maximum of three new pilots are chosen each year so the pilots of the Red Arrows really are the best of the best!

The Red Arrows have appeared in almost 5,000 displays in over 50 countries. A global television audience of over one billion people watched the flypast they performed at the London 2012 Olympic Games Opening Ceremony. The Hawks of the Red Arrows really are amongst the most famous aeroplanes in the history of aviation.

The Red Arrows Hawk is a British icon and you can recreate your own at home with an Airfix QuickBuild kit. QuickBuild kits give you the ability to recreate a wide variety of iconic aircraft, tanks and cars into brilliant scale models. No paint or glue is required, the push together brick system results in a realistic, scale model that is compatible with other plastic brick brands.

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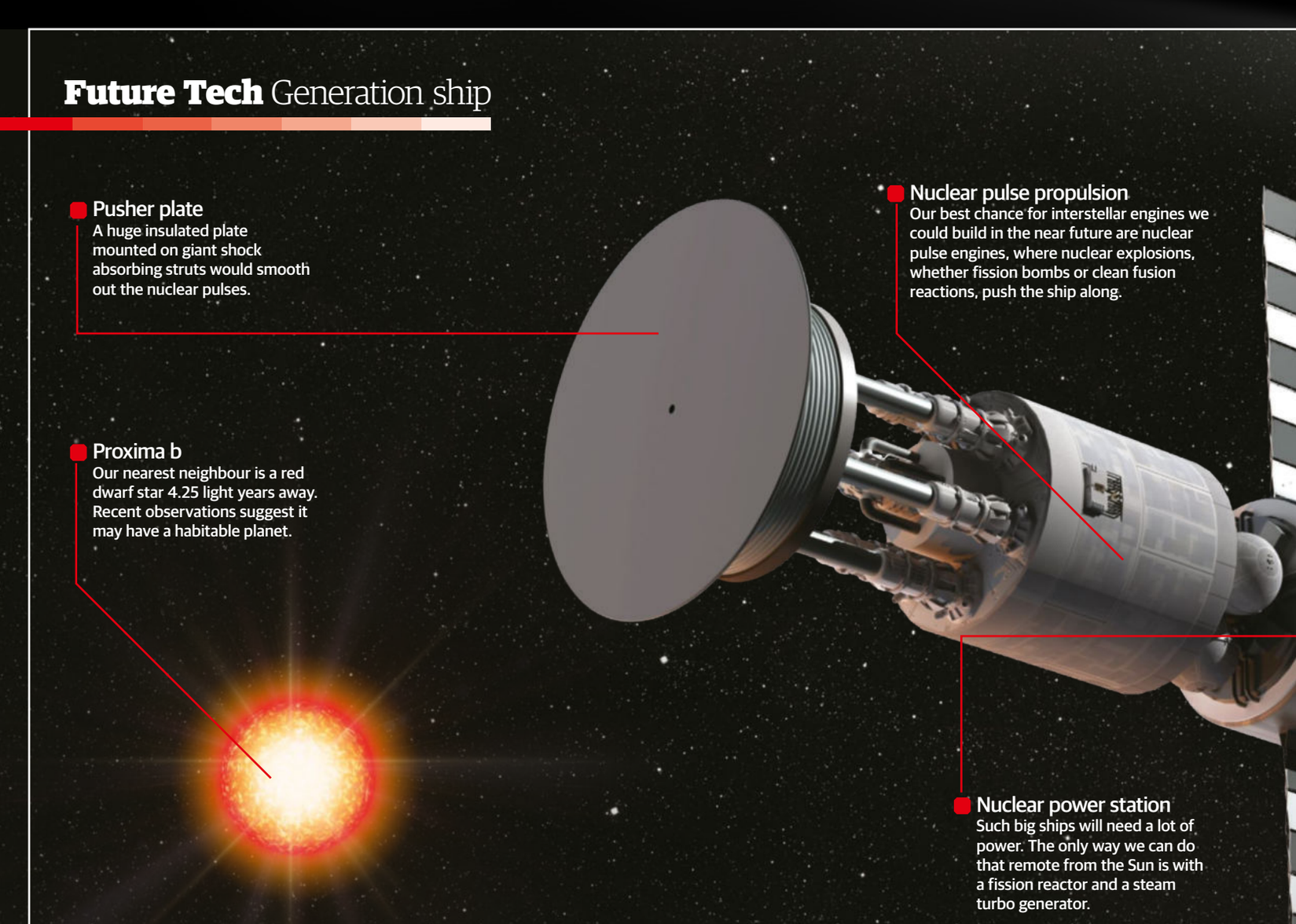


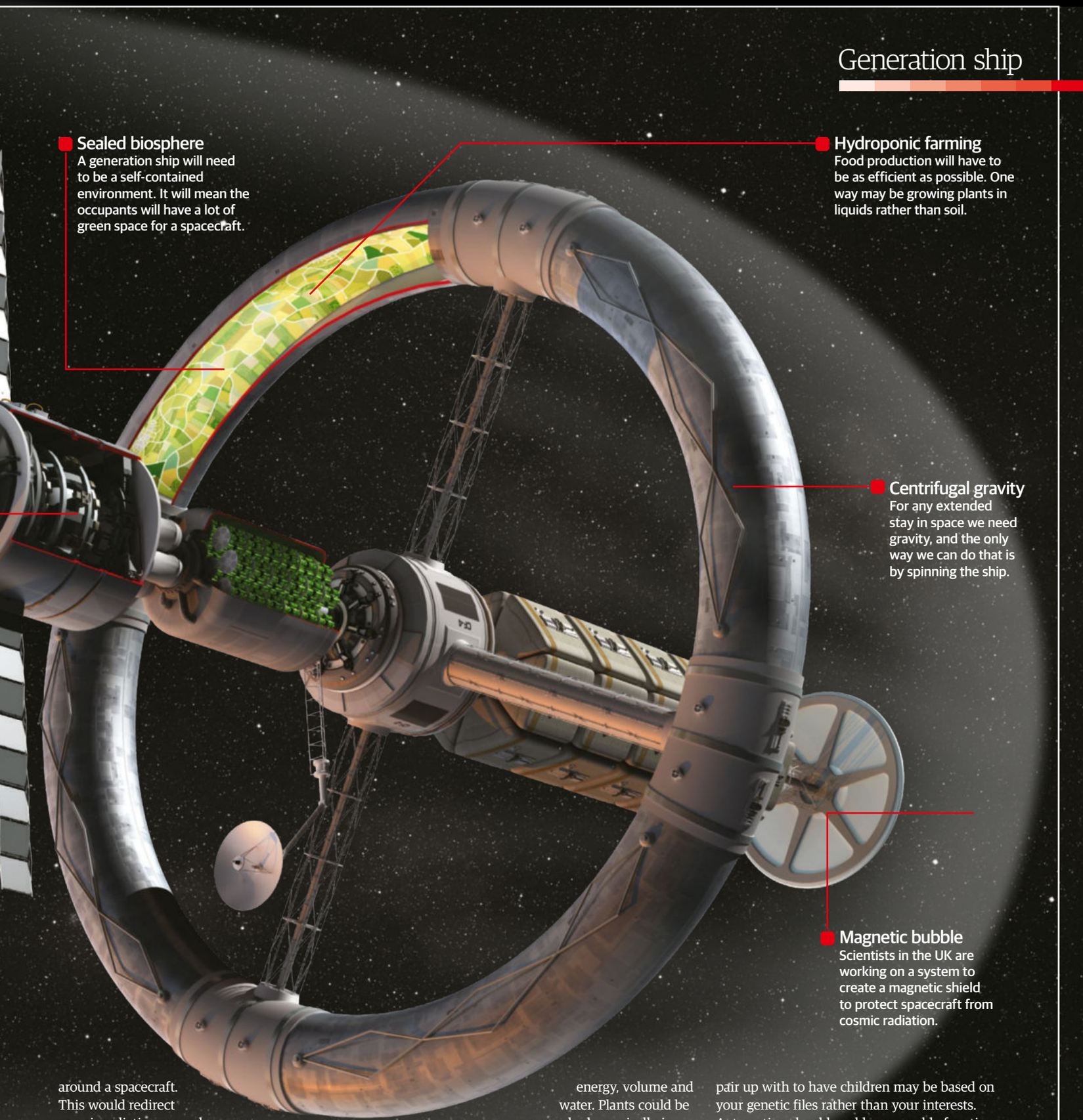
Generation ship

Barring a propulsion breakthrough, humanity's best chance of reaching other star systems could be generation ships: flying colonies that would spend centuries in transit

While we still struggle to scale interplanetary distances, various research groups have carried out serious study into interstellar travel. These distances are inconceivably vast – our nearest stellar neighbour, a red dwarf called Proxima Centauri, is about 4.25 light years or over 40 trillion kilometres (25 trillion miles) away. Though we are accustomed to the idea of skipping between star systems through fiction, barring a breakthrough propulsion discovery the best propulsion systems we can foresee would still take us a century to reach Proxima Centauri. This has led some writers and researchers to propose generation ships. A generation ship is the concept of a large, self-sustaining space colony where several generations of space travellers would live over the century, or even centuries, it would take to reach another star system. But such a ship proposes myriad questions, both technical and ethical.

To be able to make a journey a ship needs an engine, and remarkably we already have an interstellar-capable propulsion system within reach, though with one big drawback. Project Orion was a large scale, serious project studied by the US between 1958 and 1963 to propel a spaceship by detonating atomic bombs behind it. Rather than destroy the ship, bombs of just the right size would push a prospective ship along by impinging on a suspended pusher plate – like a giant atomic pogo stick! It was determined that this approach would actually be very efficient, and because the energy packets are so large the engine needs a large ship to go with it. Baseline studies proposed a 40-metre (131-foot) diameter dome weighing 4,000 tons that would be able to go from Earth's surface, to Jovian orbit and back again in a single stage. In the end it was determined that one flight to Mars would statistically kill 100 people globally by the nuclear pollution that would be sucked back to Earth by our magnetic field. But if fired up at a safe distance in a solar orbit an Orion could ultimately achieve 10 per cent the speed of light; it is an interstellar engine we already know how to build.

Another issue we need to tackle just to live in free-floating space colonies for any time, travelling or not, is radiation protection. High-energy cosmic rays and particles of all types surge around space, and without a planetary atmosphere or magnetic field humans are vulnerable to long-term damage from them. To this end researchers at Rutherford Appleton Laboratory in the UK are working on a way to generate an artificial magnetic bubble



around a spacecraft. This would redirect cosmic radiation around the ship protecting the crew, just like *Star Trek*. Initial testing is looking promising, but it will need a lot of electricity, so the ship will need its own nuclear power station on board to run everything. And there's going to be a lot to power; one study suggested the ship would need to set off with more than 160 people on board to ensure genetic diversity over the flight time. That's a big ship and a lot of people needing air and water constantly cleaned and recycled, not to mention food production. Food would have to be made as efficiently as possible using the least energy, volume and water. Plants could be grown hydroponically in liquid rather than soil, algae and mushrooms could be cultured in vats for protein, and fish could probably be effectively farmed. On top of all of that the whole structure will have to spin to provide gravity.

Perhaps larger than the technical challenges are the ethical ones; travellers setting off on a generation ship are compelling their initial descendants to spend their whole lives in a small, closed community and environment on the basis later descendants might get to settle on a new planet. To ensure a healthy community who you pair up with to have children may be based on your genetic files rather than your interests. Automation should enable reasonable free time, but to keep a closed environment running for centuries will mean career choices will be limited to what needs doing. There would also be no escape if the community turned totalitarian, or if illness struck. What about the mental well-being of the crew if 100 years into the flight a warpship turns up to collect them having been invented in the meantime?

Generation ships are probably possible within the next 100 years, but are probably only ethical if Earth is otherwise lost... Probably best if we wait on the warpdrive.

EXCLUSIVE FIRST LOOK

THE HIDDEN ARCHIVES OF APOLLO

A selection of images from the Apollo era have risen from the NASA files - and they're here to see for the first time, courtesy of Swann Auction Galleries

The Apollo archives are teeming with images that mark the golden age of space exploration – the first manned lunar exploration missions in the history of humanity. But wait... there's more.

NASA and the Swann Auction Galleries have recently released a never before seen collection of images taken from the Apollo Program (1961-1972). Between the years of 1969 and 1972, humanity explored a new frontier over the course of six manned spaceflights to the Moon, resulting in 12 American astronauts walking on the Moon, but unfortunately we haven't explored it since. This makes for a rare photo album to feast your eyes upon sights not many have seen before.

The beginning of a new era

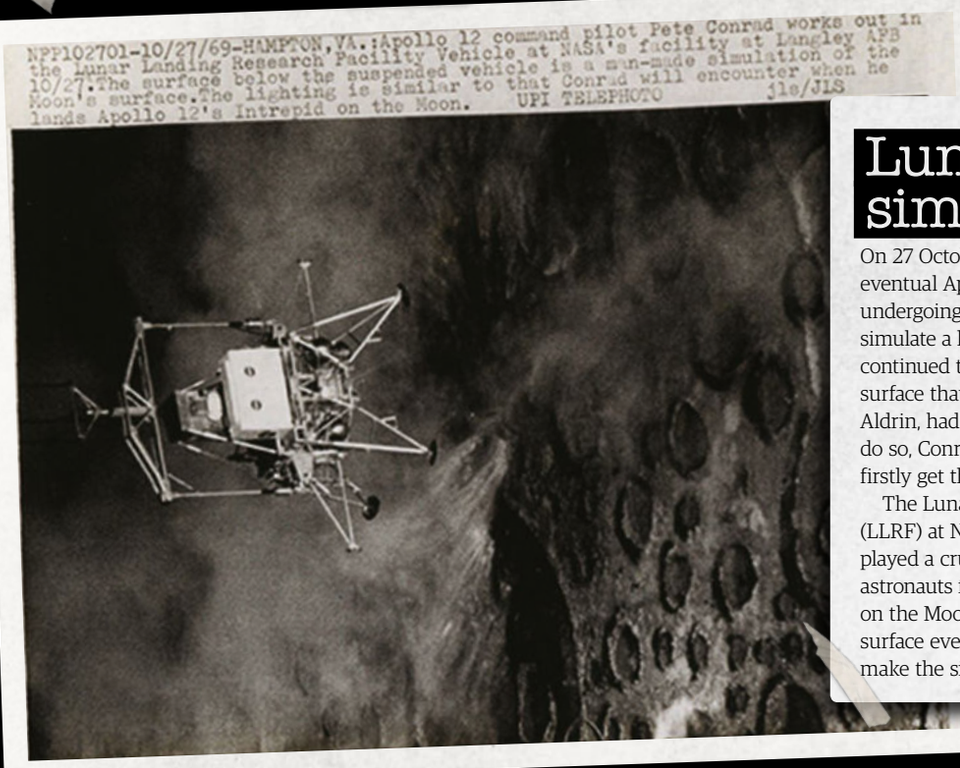
The return of Apollo 11's Lunar Module signified the end of the beginning, as this event brought a whole new dimension to the space age.

Leaving the Moon

After making history, this photo was taken from the Command Module by its pilot, Michael Collins. The half-shining Earth watched over the Lunar Module containing Neil Armstrong and Buzz Aldrin as it slowly made its return to the Command Module.

The first two moonwalkers had just spent over 21 hours on the lunar surface, of which roughly 2.5 hours were part of the moonwalk itself. The pair began their return to the Command Module at 17:54 UTC on 21 July 1969. A few hours later, Collins captured this inimitable image that unites the Earth, the Moon and humankind.

> "This mission continued the exploration of the lunar surface that its predecessors, Armstrong and Aldrin, had started"



Lunar landing simulation

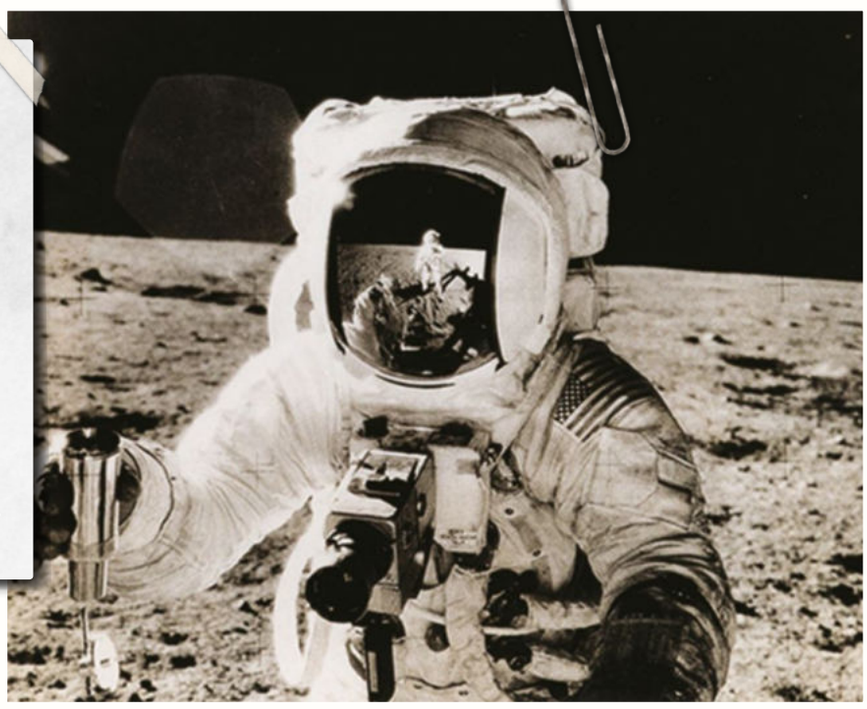
On 27 October 1969, NASA photographed the eventual Apollo 12 commander, Pete Conrad, undergoing intense training designed to simulate a lunar landing. This mission continued the exploration of the lunar surface that its predecessors, Armstrong and Aldrin, had started. However, in order to do so, Conrad had to make sure they could firstly get there safely.

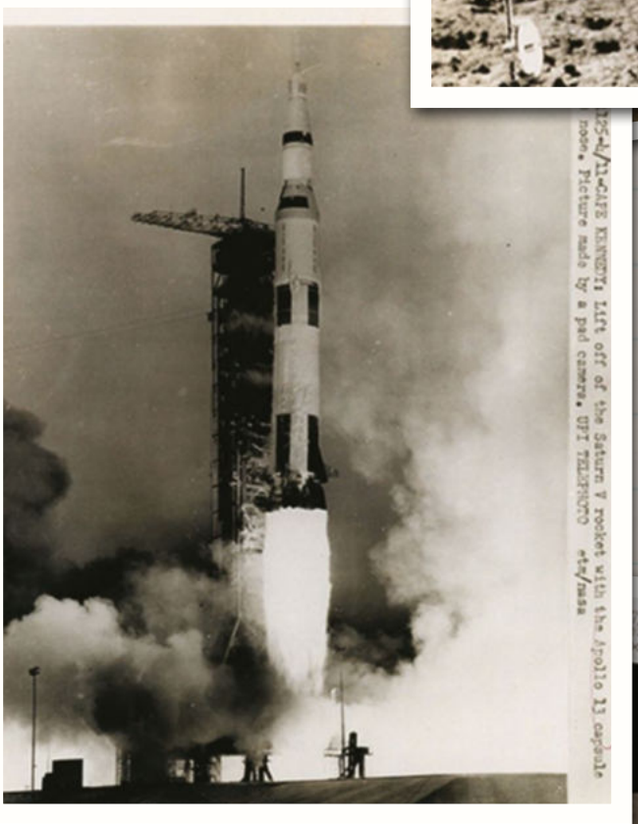
The Lunar Landing Research Facility (LLRF) at NASA's Langley Research Center played a crucial role in preparing the Apollo astronauts for the flight, landing and walking on the Moon's alien environment. The surface even had craters on it in order to make the simulation more realistic.

Apollo 12 men at work

While busy at work on the Moon, Pete Conrad took this great shot of Alan Bean. Here Bean is holding the vacuum-sealed Special Environmental Sample Container (SESC) that has been filled with lunar soil for study back on Earth. This picture was taken in November 1969 at Sharp Crater.

From the angle of this image you get a view of Bean's Hasselblad camera, which has been mounted onto the chest of his spacesuit. Conrad's reflection can also be seen in Bean's helmet visor, as well as the Hand Tool Carrier.





Apollo 13 lift off

The third lunar landing attempt was to be a 'successful failure'. The Apollo 13 crew consisted of James Lovell, Fred Haise and John Swigert, who intended to land in the Fra Mauro region of the Moon. But, two days after launch an oxygen tank exploded and they were forced to abandon the landing. Instead they orbited the Moon, and eventually returned safely to Earth.

On 11 April 1970, none of the astronauts aboard the Saturn V rocket at Kennedy Space Center in Florida, United States, thought they'd have such an ordeal ahead of them.

What about a photo?

It is a little-known fact that Bean and Conrad also had a colour video camera on the Moon, but it was broken after Bean pointed the camera at the Sun, ruining the optics.

Apollo 12 success

This photo was taken when Pete Conrad and Alan Bean walked on the Moon, making them the third and fourth men respectively to do so. These two astronauts doubled the number of Extra Vehicular Activities (EVAs) performed by Apollo 11... to two. Each moonwalk walks lasted roughly four hours.

On the first EVA, Conrad and Bean deployed part of the Apollo Lunar Scientific Experiments Package (ALSEP), and this is what is photographed here. ALSEP was placed at each Apollo landing site – except Apollo 11 – with the aim of relaying long-term data from the lunar surface.

Crescent Earth

Shown in this particular image is the crescent Earth shining over the uneven cratered surface of the Moon. It cannot be said with certainty what mission this is due to the lack of image description, however, based on the images of other Apollo missions, this one was most likely taken on the last ever mission, Apollo 17.

This conclusion is drawn from Apollo 17 images that were taken from the Apollo 17 Command Module while in lunar orbit. If true, this image would be the most recent image out of the collection.

Celebrations for Apollo 11's astronauts

(From left to right) Aldrin, Armstrong and Collins returned to Earth as heroes. These were the first men to not only travel to the Moon, but also have two of the three descend to its surface and walk where no one had ever walked before.

These three brave men were welcomed back – after 21 days in quarantine – with a ticker tape parade through the streets of Chicago, United States, where an estimated 1 million people turned up on the 13 August 1969. Here, the trio are pictured travelling down LaSalle Street, Chicago.

Over the Moon

Another Apollo mission, another launch from the Kennedy Space Center. At the tip of this particular Saturn V rocket would eventually sit Apollo 12's commander Pete Conrad, Lunar Module pilot Alan Bean and Command Module pilot Richard Gordon. At the time of the image, the Saturn V sat empty.

Overlooking the Apollo 12 rocket here was their target, roughly 380,000 kilometres (236,000 miles) away. The Saturn V rocket, shone brightly upon by searchlights, was pictured during a test countdown on the 27 October 1969, which had the service tower move away during the process of the test.

"In this image you see the mystery astronaut simulating lunar soil collection, along with the Lunar Module in the background"

Preparing for lunar science

There are images in this selection that show astronauts actually on the Moon, collecting samples and conducting real science, although this is the only image that shows them practising these procedures.

Due to the lack of image description, it cannot be said with certainty who this astronaut is, or what mission this is. After going through the other archive images, the best bet is either Jim Lovell or Fred Haise preparing for Apollo 13. In this image you see the mystery astronaut simulating lunar soil collection, along with the Lunar Module in the background.

James "Jim" Arthur Lovell Jr.

NASA pictured Jim Lovell, flight commander of the Apollo 13 mission, prior to his departure from the Kennedy Space Center. Suited up in the iconic Apollo spacesuit, Lovell would not actually land on the Moon, but along with his crew would navigate the damaged Command and Service Module, Odyssey, back to Earth.

Approximately 330,000 kilometres (205,000 miles) from Earth, the crew were forced to abandon Odyssey and use Aquarius – the lunar module – as a 'lifeboat'. But the question was whether these astronauts would come home alive? Six days after they left Earth they did, in what has been termed NASA's finest hour.

The Apollo spacesuits

The spacesuits that were worn on each Apollo space flight were made up of different layers of nylon, aluminised Mylar, Kapton and Teflon for the ultimate protection.

Looking back at Apollo 11

At the landing site referred to as 'Tranquillity Base' on the Moon, Neil Armstrong snapped this picture of his fellow astronaut Buzz Aldrin, as indicated by the name on his chest piece. When looking at his reflective faceplate, a lot more of the scene is unveiled, including Armstrong himself, a section of the Lunar Module, the solar wind experiment and the United States' flag. The fact that this picture is from one of – if not the – most iconic events ever, and hasn't been released until recently makes it all the more surprising and extraordinary.

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PLU

PLUTO IS IT MADE FROM COMETS?

A new revelation about the dwarf planet has left astronomers once again questioning its identity

Reported by Lee Cavendish

The scientific community has always had a problem with Pluto's status. The icy world's demotion to a dwarf planet in 2006 still burns strong for some, whilst others still refuse to even accept its new position. The identity crisis has now resurfaced with a new theory that claims that it could actually be roughly a billion comets all squished together. If this theory is proven true then this is just another nail in the coffin for Pluto and the argument to allow it to join the 'fully-fledged' planetary family once again.

There were several factors that knocked Pluto from its planetary pedestal, but the instigator was the uprising discoveries of other dwarf planets such as Eris, and other Kuiper Belt Objects (KBOs). The Kuiper Belt is the region beyond the orbit of Neptune from about 30 Astronomical Units (AU) to 55 AU, with one AU being the distance between the Sun and Earth. The objects in this region are thought to be the remnants from the formation of our Solar System around 4.6 billion years ago.

Left: Rosetta was the first spacecraft to visit a comet in 2015

Right: Pluto's varied terrain includes ice mountains

"Without New Horizons, we would have no idea how much nitrogen is on Pluto. Without Rosetta, we wouldn't know how much nitrogen is in comets" **Dr Christopher Glein**

"This work helps us to understand the origin and evolution of Pluto, which is a supreme challenge at over 30 AU," Dr Christopher Glein of the Southwest Research Institute's Space Science and Engineering Division in San Antonio, Texas, United States tells **All About Space**. "This is important for learning about the conditions of planetary formation in the early outer Solar System, and the processes that have modified the initial composition to produce the Pluto we all know and love today."

The most widely accepted theory for the formation of the planets is the Nebular Hypothesis; they formed from a spinning cloud of dust and gas surrounding the young Sun. The spinning motion of the cloud caused it to get thinner and flatten (like spinning pizza dough) to form a protoplanetary disc - the birthplace of the planets. Here, microscopic grains of material began to collide and stick together, and they increased in size until they developed a significant enough gravitational force to attract even more and more surrounding material. These are the building blocks of our planets, and are known as planetesimals.

This began an era of collisions and continuous smashing which formed the Solar System we see today. It is this period of madness that astronomers wish they could jump into a time machine to go back and see, as it would answer so many bewildering questions about the Solar System and, for the sake of this argument, Pluto. Alas, technology is not quite capable of that, so all astronomers have to go on is the data that is laid out in front of them.

Pluto is a highly intriguing figure in the Solar System, and has caused much controversy; it still remains an enigma. On the 14 July 2015, NASA's New Horizons spacecraft made the near ten-year journey, over five billion kilometres (three billion miles) to Pluto. In a flyby that got as close as 12,500 kilometres (7,767 miles) to the surface of the icy dwarf planet, New Horizons' incredible suite of instruments gathered as much data as possible before journeying further into the Kuiper Belt region.

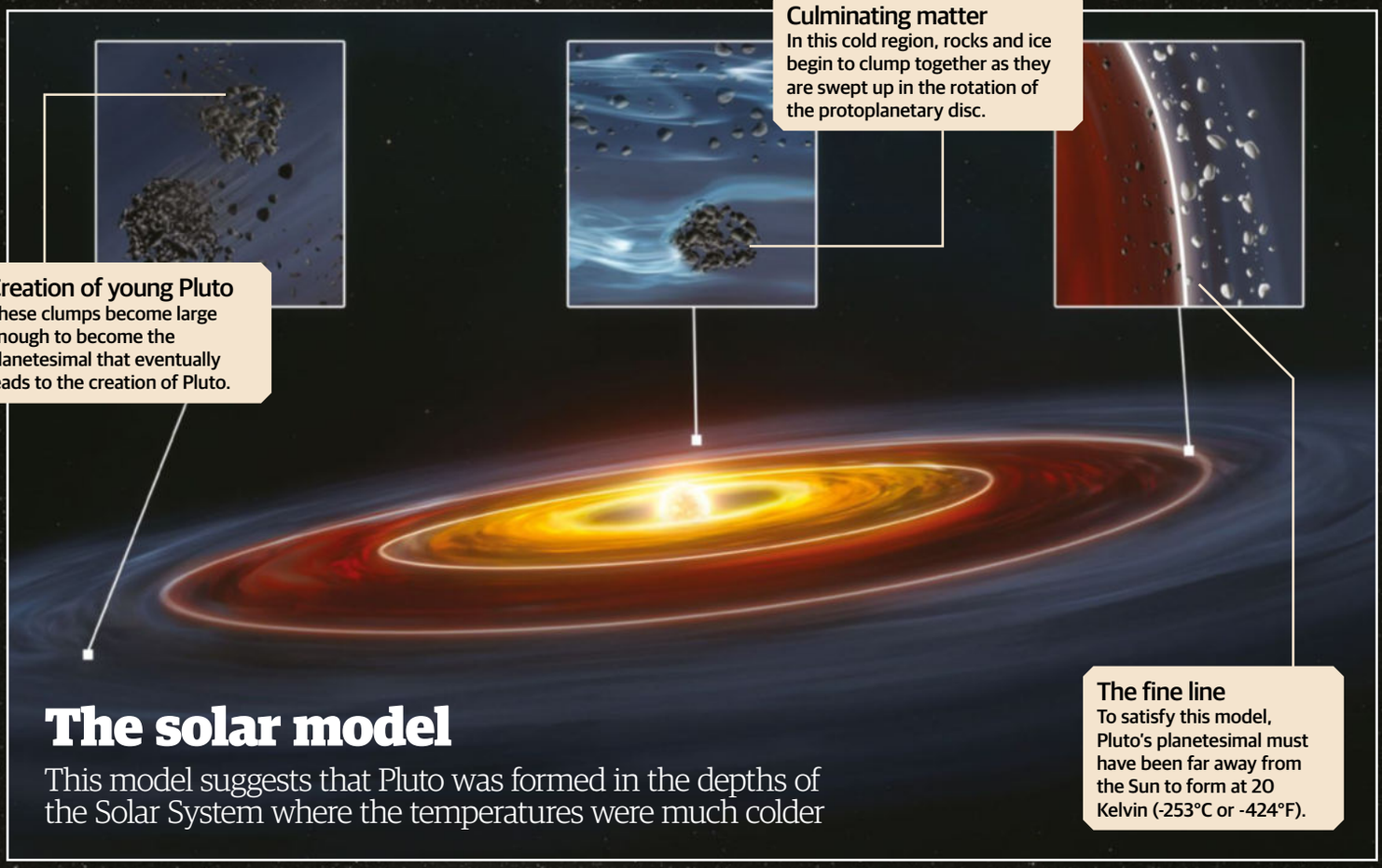
During this period, New Horizons saw a plethora of exciting surface and atmospheric attributes that had scientists bouncing off the walls. "We [the New Horizons team] got there and we found flowing glaciers and young terrains on a vast scale, which were created yesterday. We found evidence of mass motion of atmospheric waves. We found volcanoes that were geologically young on the surface, known as cryovolcanoes. Any one of these things alone would have been a headline, but to see them all was just stunning, and really, I don't think anyone understands how Pluto does this," Dr Alan Stern, principal investigator of the New Horizons mission, tells **All About Space**. "But it's taught us now to expect that other small planets in the Kuiper Belt are likely to also be geologically active after long periods and that's a fundamental paradigm shift in the field of planetary science."

It is these discoveries that have completely changed the outlook on Pluto and the Kuiper Belt region. It has made scientists such as Glein think outside the box, particularly about their formation.

The Kuiper Belt is not only home to dwarf planets and other such Kuiper Belt Objects, it also accommodates many comets. These distant balls of ices and dust – hence their nickname 'dirty snowballs' – have been considered as the possible building blocks for planets for a while among members of the astronomical community.

In August 2014, the European Space Agency (ESA) was successful in having

Stern is the principal investigator of the New Horizons mission



Culminating matter
In this cold region, rocks and ice begin to clump together as they are swept up in the rotation of the protoplanetary disc.

Creation of young Pluto
These clumps become large enough to become the planetesimal that eventually leads to the creation of Pluto.

The solar model

This model suggests that Pluto was formed in the depths of the Solar System where the temperatures were much colder

The fine line
To satisfy this model, Pluto's planetesimal must have been far away from the Sun to form at 20 Kelvin (-253°C or -424°F).

The cometary model

This model is the most likely scenario out of the two, and predicts the aggregation of a billion comets

Slung further out
This vast accumulation of comets was then thrown out into the depths of the Solar System after some event.

Colliding comets
This model predicts that comets collided in the young Solar System, much closer to the Sun than the solar model.

New home
The new Pluto is then sent into orbit before reaching stability and orbiting as astronomers know today.

Chris Glein (pictured) is interested in the detection of molecular nitrogen on Comet 67P

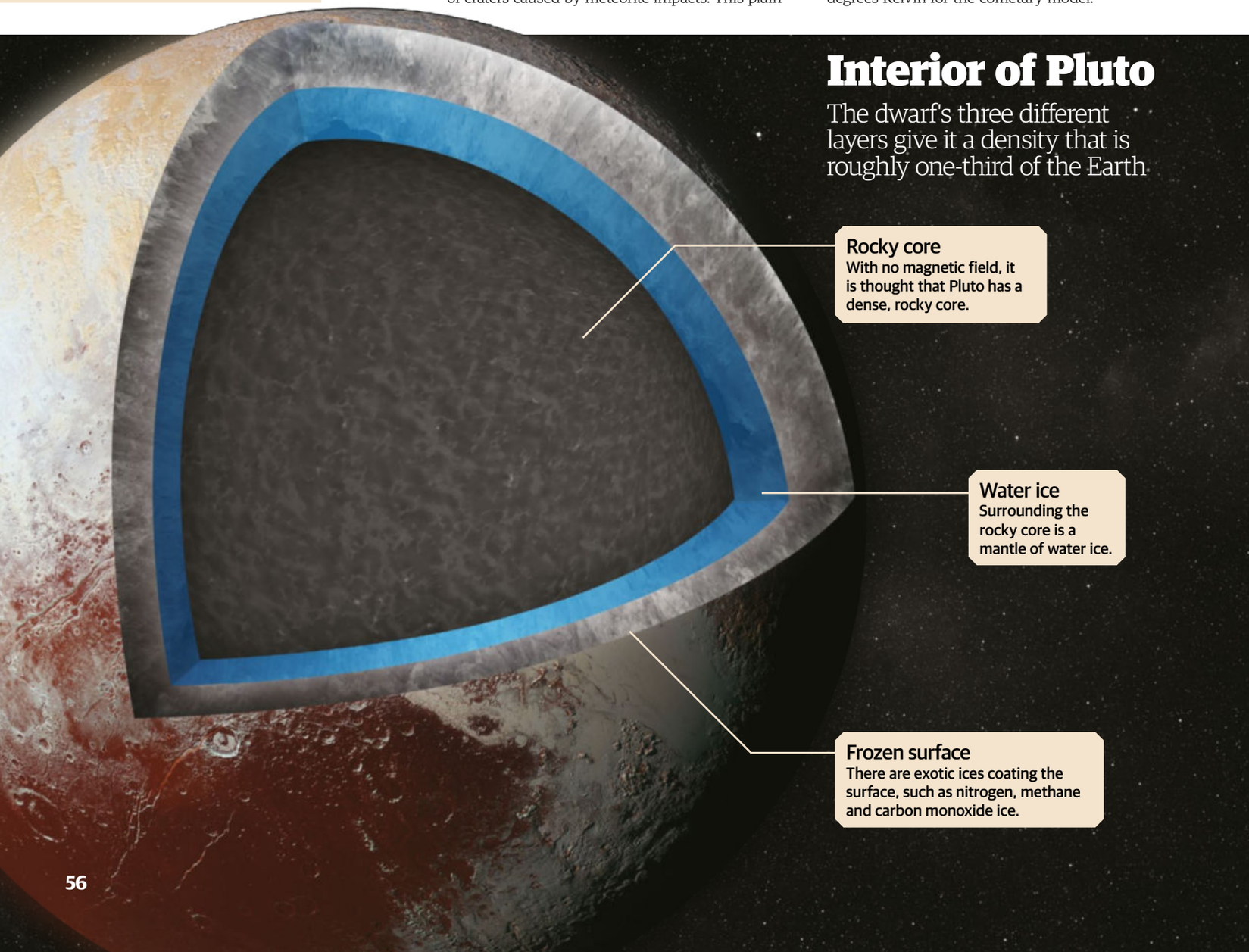
the first human-made spacecraft visit one of these dirty snowballs. The Rosetta orbiter rendezvoused with Comet 67P/Churyumov-Gerasimenko and, three months later, its Philae lander touched ground on comet terrain for the first time in history. The science gathered from this extraordinary mission again brought in a new era of understanding when it comes to these mysterious mini-worlds. Among the many discoveries about comets was one that bears great interest to Glein's research, and that is the detection of molecular nitrogen (N_2) in the comet's water by Rosetta.

These two missions are what have paved the way to this new theory that Pluto was initially formed from the culmination of a billion comets. "This research would have been impossible without both of these missions. Without New Horizons, we would have no idea how much nitrogen is on Pluto. Without Rosetta, we wouldn't know how much nitrogen is in any comets," explains Glein.

The main area of investigation was the western lobe of Pluto's famous 'heart', formally known as Tombaugh Regio. When New Horizons flew past this lobe, in the Sputnik Planitia region, it found that this bright and icy plain is relatively young at no more than 100 million years old, due to the lack of craters caused by meteorite impacts. This plain is covered in a freezing glacial sheet of nitrogen-rich ices, with temperatures as low as -240 degrees Celsius (-400 degrees Fahrenheit) on the surface of Pluto. In an attempt to gain insight into the dwarf planet's past, Glein and his collaborators estimated the formation of Pluto in its earlier years based on models using nitrogen-based data of its planetary and atmospheric chemical conditions.

Two main theories arose from this work: one called the 'cometary model' and other the 'solar model'. These two models are largely based upon exploring the possibility of Pluto forming from building blocks with two different chemical compositions. The cometary model suggests that these building blocks had a nitrogen abundance similar to a comet, which is compared to the results from ESA's Rosetta mission at Comet 67P. Playing the devil's advocate is the solar model, which suggests Pluto formed from cold ices that would have had a chemical composition similar to the Sun.

"The chief difference between them is the formation temperature of the building blocks," says Glein. "Because the solar model is richer in nitrogen, a lower formation temperature is required. [It's] probably closer to 20 degrees Kelvin [-253 degrees Celsius] for the solar model, while closer to 30 degrees Kelvin for the cometary model."

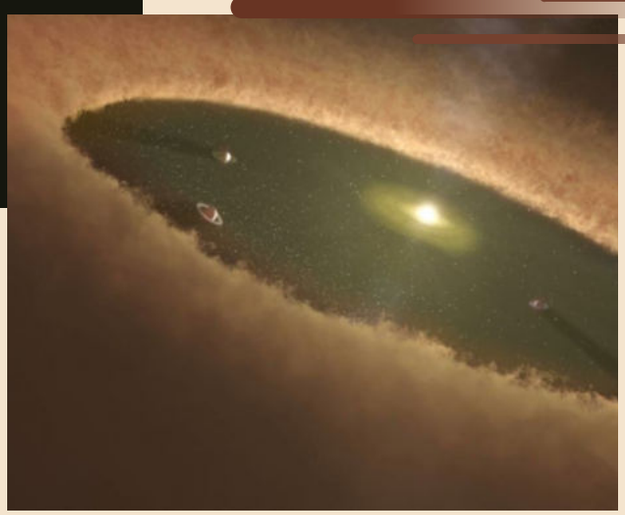


What makes a planet, a planet?

Discovered on 18 February 1930, Pluto was considered our Solar System's ninth planet for nearly eight decades. Then, on 24 August 2006, after the discovery of other similarly mysterious worlds in the Kuiper Belt, the International Astronomical Union created three criteria for planet status:

1. It is in orbit around the Sun.
2. It has enough mass that its own gravity pulls itself into a (nearly) round shape.
3. It has cleared the neighbourhood around its orbit.

Pluto does not meet criterion number three, causing it to fail as a planet and be reclassified as a dwarf planet – one of five in our Solar System.



Above: New Horizons was the first reconnaissance mission with a dwarf planet

Right: The Solar System started to form approximately 4.6 billion years ago

"Unless we bring more instruments there, we are never going to figure this place out. We need an orbiter" **Dr Alan Stern**

Generally, it is safe to assume that the closer to the Sun an object is, the warmer the environment is. This is why, based on Glein's comments, it is inferred that the cometary model suggests Pluto was most probably formed closer to the Sun compared to the solar model. Although it's impossible to predict exactly what happened in either scenario, the solar model predicts Pluto formed from a planetesimal in the outer region of the early Solar System. This planetesimal accreted enough surrounding material, including comets, to develop into the Pluto we see today.

The other theory that is being suggested, and the more likely theory according to in-depth analysis, is that roughly a billion comets bundled together closer to the Sun. Being closer to the Sun also means that some event had to throw it out into the Kuiper Belt where it resides now. This could have been from a planetary migration that scattered Pluto, among other objects, into the Kuiper Belt, or there could have been a collision that sent the dwarf planet flying outward. "If my hypothesis is correct, then the widely suspected, but unconfirmed notion of comets as building blocks of the outer Solar System would be supported in an analogous fashion to the role of meteorites and asteroids in the inner Solar System," explains Glein.

This theory has now instigated an expedition that hopes to find the first evidence for comets being actual building blocks to planets. If scientists could make a clear link between the two, with Pluto being the dwarf planet 'bridge' between them, then scientists would have more pieces to the puzzle that is our Solar System's formation and evolution. However, this is just the tip of the iceberg. A lot more work has to be done before scientists can make clear definitive statements about Pluto's – and other planets' – beginnings.

When it comes to Pluto, Stern believes an orbiter like Rosetta would bring the valuable information about Pluto which astronomers' hearts desire. "Unless we go back [to Pluto] with instrumentation that can penetrate the ice with radars, see how deep it is and determine the surface images better with having high-resolution cameras and spectrometers... unless we bring more instruments there and watch the time variability, we are never going to figure this place out. So we need an orbiter," Stern explains.

Although Stern does have an eye set on going back to Pluto for further exploration, he has another eye set on New Horizons' next target, KBO (486958) 2014 MU69, given the nickname 'Ultima Thule' by NASA. Due to arrive at Ultima Thule on New Year's Day of 2019, New Horizons will fire up its instrumental suite again to observe a frozen block of rock leftover from the Solar System's formation hidden in its darkest, deepest realm. When asked if Ultima Thule could make a possible impact on this research, Glein replies, "It could. I will be eager to see if New Horizons finds any nitrogen ice on that body. What's intriguing is that Ultima is intermediate in size between comets and Pluto, so perhaps it can serve as a missing link between them. This could help to clarify their compositional relationships."

If the Solar System is the human body, then Pluto is a human cell. KBOs such as Ultima Thule are a strand of DNA, and comets are the atoms that constitute everything. The body of the Solar System seems to be the same at first glance, but it seems to be ever-changing with whatever new data and analyses come our way. With new missions being commissioned and new targets acquired, Pluto's past will become more clear. For now we still have to ask, is Pluto really a planet?

USER MANUAL

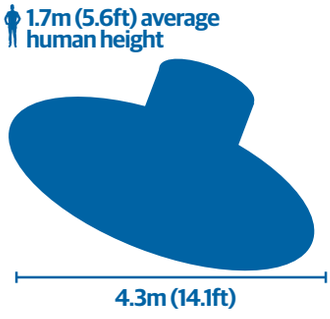
Gaia

For over four years, the Milky Way mapper pinpointed over a billion stars to create an expansive dataset

Gaia will not only map the stars within our galaxy, but will provide more insight into the galaxy's composition, formation and evolution

THE SPECS

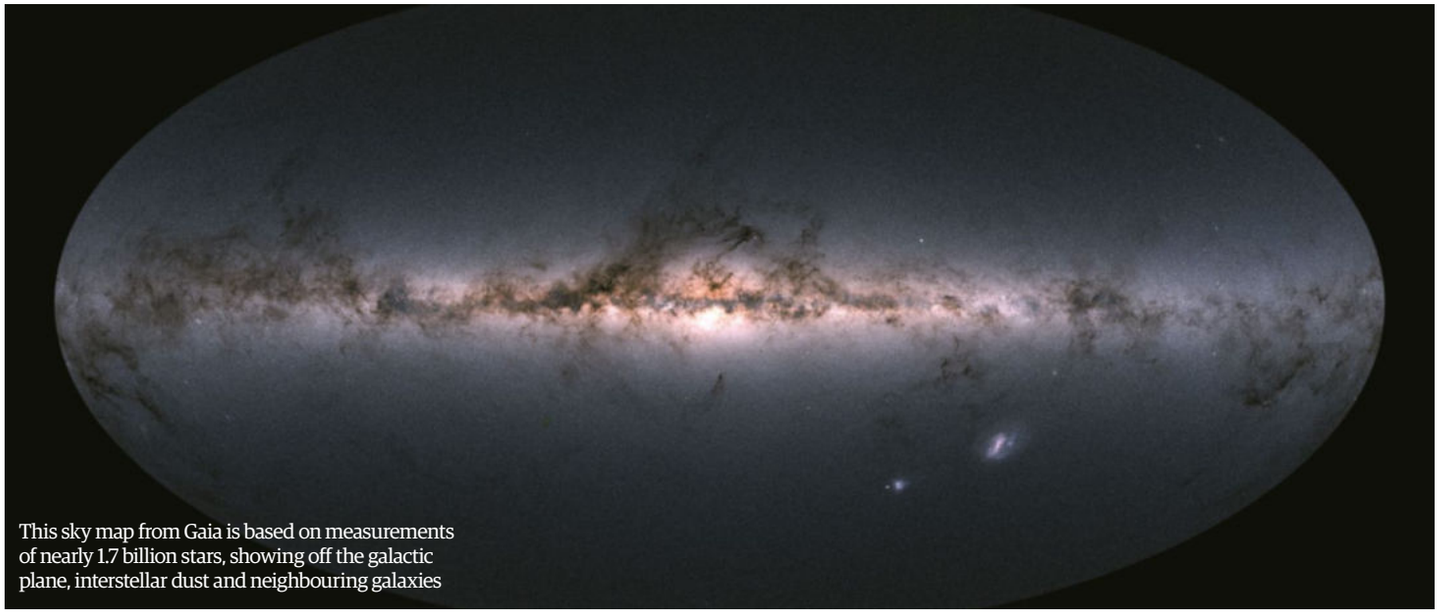
Launch: 19 December 2013
Rocket: Soyuz-STB/Fregat-MT rocket
Target: Lagrangian point 2
Operator: European Space Agency
Estimated cost: £650 million ($860 million)
Time in space: Nearly five years
Distance from Earth: 1.5 million kilometres (932,057 miles)



This almost sombrero-shaped spacecraft has been mapping the stars for more than four years. Its recent data release contains unrivalled information on nearly 1.7 billion stars, and is to date the greatest catalogue of stars ever produced. The European Space Agency (ESA) initially had the idea of using Gaia as an optical interferometer mission, meaning that Gaia originally would have been a series of smaller telescopes working together to create an image similar to that from a larger telescope. Thus ESA gave the mission its original name: the Global Astrometric Interferometer for Astrophysics, or GAIA. After the mission evolved and the interferometer idea was dropped, the name stuck. However, the previous design was altered and Gaia's primary objective would be to create the largest, most precise three-dimensional map of the stars in our galaxy within its intended five-year mission, building on the legacy of their Hipparcos mission.

The name change wasn't the only aspect that changed plans for Gaia, as too was its launch, originally scheduled for December 2011. After a series of complications to Gaia and the liftoff schedule the spacecraft finally left Earth two years behind schedule, riding aboard a Soyuz-Fregat rocket. With a launch mass of 2,030 kilograms (4,475 pounds), Gaia was sent on its way to its new home at Lagrange point 2 (L2) roughly 1.5 million kilometres (932,057 miles) away from Earth. This is an ideal location to observe the wider universe, and a cosmic 'parking spot' which relies on the gravity of the Sun and Earth to keep the space observatory fixed in this one spot. While at L2 Gaia is in a Lissajous-type orbit that has a period of about 180 days around a fixed point at L2.

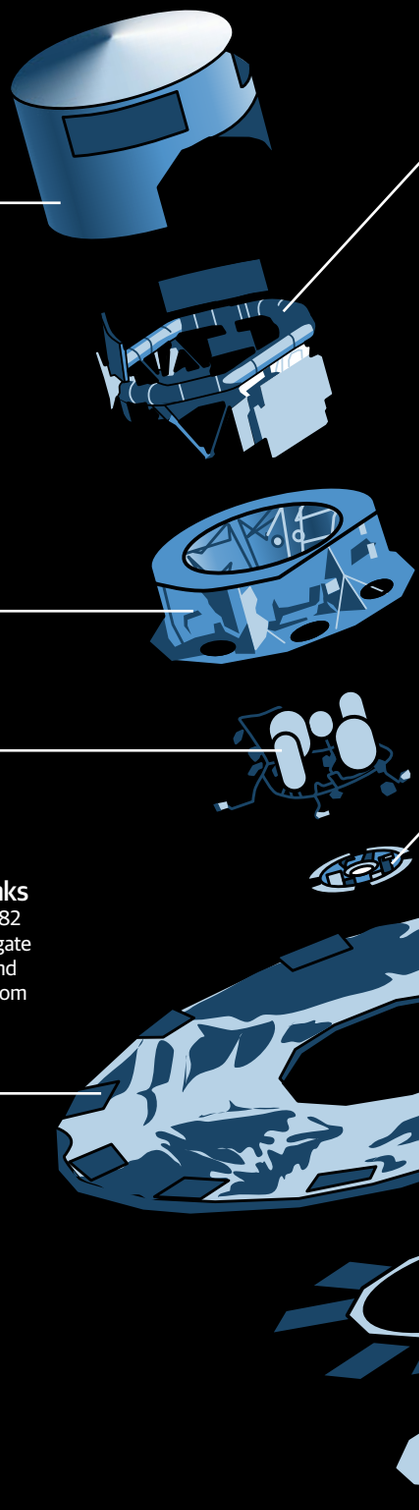
Before Gaia could examine the sky properly there were some hiccups. The Gaia team needed to sort out issues with the optics, including some areas of water freezing and 'stray light', where some of the Sun's light was making its way into Gaia's focal plane. On 25 July 2014, Gaia officially began its science mission and could start scanning the sky. On average, Gaia observes each single star, of the intended billion stars, 70 times over the course of its five years. Sweeping the skies once every six hours, the two onboard telescopes focus the light that is measured by three major instruments fixed on the same focal plane. The focal plane can be thought of as the largest space camera ever created, consisting



This sky map from Gaia is based on measurements of nearly 1.7 billion stars, showing off the galactic plane, interstellar dust and neighbouring galaxies

Anatomy of Gaia

The ESA spacecraft is fitted with the finest equipment intended to detect any speck of light coming from any section of the sky



Thermal tent
This thermal tent will cover the payload module and protect it from being exposed to extraneous radiative thermal inputs.

Payload module
The module accommodates the two telescopes and electronics, including its 106 CCDs, in order to manage and process the raw data collected.

Service Module
This module contains equipment to maintain basic control of the spacecraft such as providing power, storing data and processing video data.

Antenna support panel
Also containing the phased array antenna, this antenna has to be powerful enough to send data over 1.5 million kilometres (932,057 miles) back to Earth.

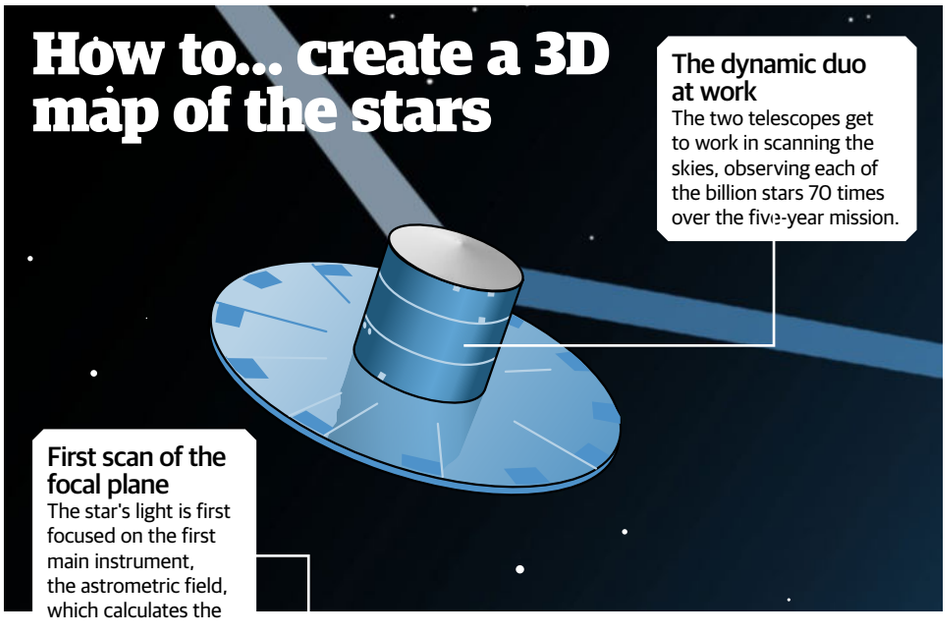
Solar panels
There are eight solar panels that are attached to the outside of the deployable sunshield. These collect the Sun's light and harness it for energy to power the spacecraft.

Propellant and pressurant tanks
At launch there was 400 kilograms (882 pounds) of propellant in order to navigate the spacecraft to L2, keep it in orbit and orientate its main instruments away from the Sun's light.

Deployable sunshield assembly
Stretching out to roughly 10.2 metres (33.5 feet), the sunshield protects Gaia's sensitive instruments and helps keep them cool at -100 degrees Celsius (-148 degrees Fahrenheit).

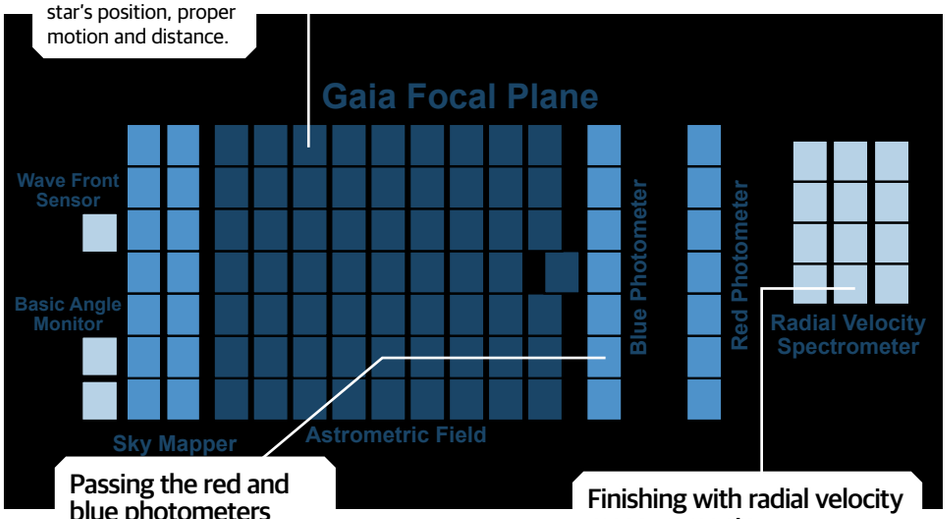
Fixed solar array
Fixed at the base of the spacecraft, this solar array will harness power similar, to the solar panels above, but it will not blossom in the same fashion.

How to... create a 3D map of the stars



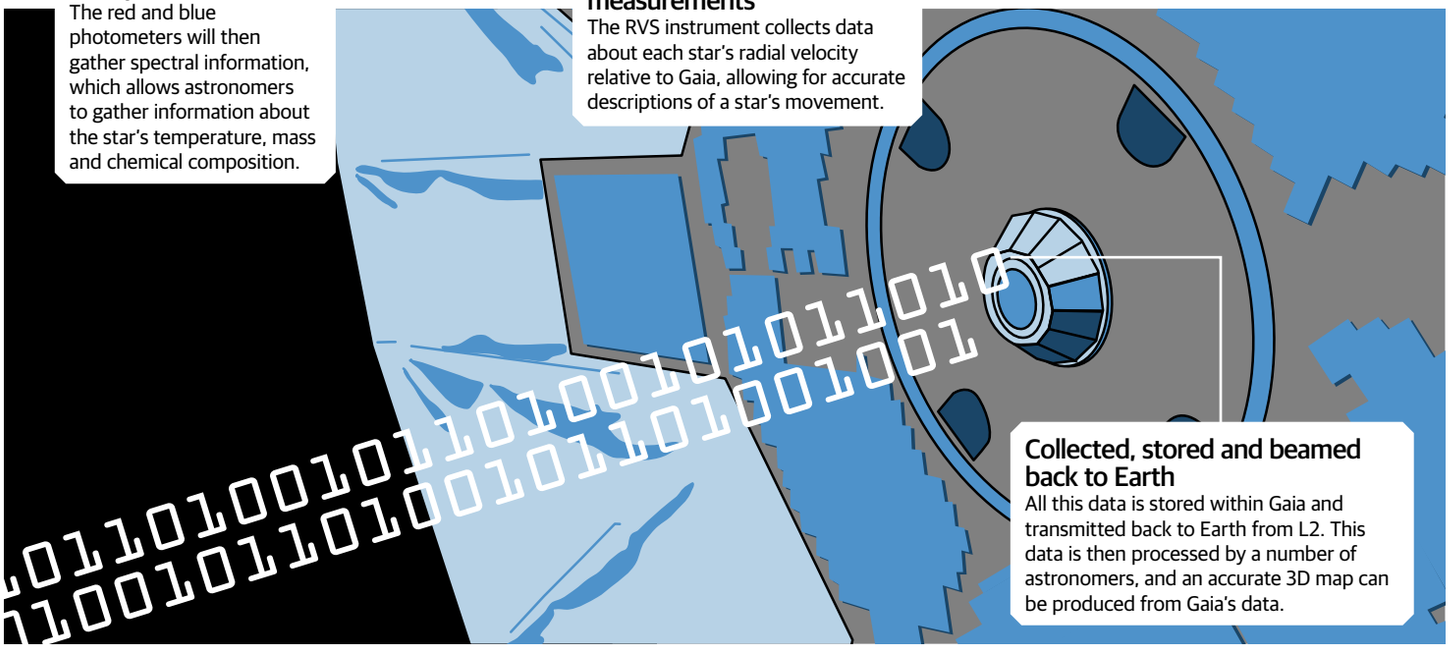
The dynamic duo at work
The two telescopes get to work in scanning the skies, observing each of the billion stars 70 times over the five-year mission.

First scan of the focal plane
The star's light is first focused on the first main instrument, the astrometric field, which calculates the star's position, proper motion and distance.



Passing the red and blue photometers
The red and blue photometers will then gather spectral information, which allows astronomers to gather information about the star's temperature, mass and chemical composition.

Finishing with radial velocity measurements
The RVS instrument collects data about each star's radial velocity relative to Gaia, allowing for accurate descriptions of a star's movement.



Collected, stored and beamed back to Earth
All this data is stored within Gaia and transmitted back to Earth from L2. This data is then processed by a number of astronomers, and an accurate 3D map can be produced from Gaia's data.

The sunshield is vital in powering the spacecraft, as well as keeping the instruments cool

of 106 CCDs and equating to an enormous 1 billion pixels. The first instrument, the astrometric instrument (Astro), is devoted to measuring a star's position, proper motion and parallax (therefore its distance). The second, the photometric instrument (BP/RP), consists of a blue and a red photometer, and they provide information about a star's temperature, mass and chemical composition. Lastly, the third instrument, which is the Radial-Velocity Spectrometer (RVS), measures how fast a subset of stars are moving relative to Gaia.

Throughout the years Gaia has not experienced many other hiccups, and has proven successful in its quest for stellar knowledge. This is shown in its two major data releases, the first of which came out on 14 September 2016 and the second more recently on 25 April 2018. The first release detailed the precise position and brightness of over 1.1 billion stars, which at the time was the most detailed 3D map ever created.

After a period of 22 months of data collection, a second catalogue was released and scientists marvelled at the results; the position and brightness of 1,692,919,135 stars was found! For some of the brightest stars in this survey, the level of precision was so good that it would be similar to an observer on Earth being able to locate a pound coin lying on

> "The position and brightness was found for a total of 1,692,919,135 stars"

the surface of the Moon, which on average is about 384,000 kilometres (239,000 miles) away.

The image of the night sky created by Gaia's second data release is iconic. The mixture of light stretching across the plane of the Milky Way, blocked in many places by intergalactic dust and our two neighbouring galaxies, the Small and Large Magellanic Clouds, is a real thing of beauty. To think that each dot of light is a star that has been watched for over four years is extremely humbling and inspiring.

The dataset that Gaia has produced as part of this amazing project will certainly keep scientists busy. The data collected also includes information on more than 550,000 variable stars, which are stars that change brightness over time; velocities for over 7.2 million stars; the surface temperatures for over 160 million stars and also data on Solar System objects. Although Gaia was originally planned to be a five-year mission, ending operations in mid-2019, ESA has approved an extension until the end of 2020, and this is due to be confirmed at the end of this year. A final catalgoue based on data from the five-year mission is planned for 2022.

TOP TECH

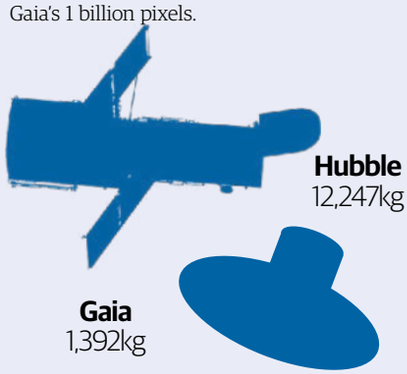
Gaia's digital detectors: the billion-pixel camera

Gaia contains the largest camera to ever leave Earth, consisting of 106 CCDs that makes up almost a billion pixels. Compared to the Apple iPhone 8's 12 million-pixel camera, Gaia's camera is over 80-times more impressive. These CCDs are split up into subsections that make up the three main instruments: the astrometric field, the photometric instrument and the radial velocity spectrometer, including some minor instruments that track the motion of stars and re-align the telescope. As a team, these CCDs are what make Gaia a success.

Head-to-head
Gaia vs Hubble

With regards to physical dimensions, Hubble towers above Gaia. With Hubble being 13.2 metres by 4.2 metres (43.3 feet by 13.8 feet), NASA/ESA's space telescope is about three-times as long and almost twice as wide as ESA's space observatory. In terms of launch mass, Hubble also reins supreme, as it was 8,856 kilograms (19,524 pounds) heavier.

Gaia does have a much larger collective focal plane though, as Hubble is made up of different cameras, the two main ones being the Advanced Camera for Surveys (ACS) and the Wide Field Camera 3 (WFC3), and each of these have 16 million pixels, compared to Gaia's 1 billion pixels.



Vital statistics

10.2 metres, the width of the sunshield = About one-fifth as tall as the Statue of Liberty

2,030kg The launch mass = Roughly the weight of two cows

1.5 *million kilometres* = Roughly 37 Earth orbits

70 *billion images* = Over 1 billion observations each month

1 *billion stars* Total number of stars observed by Gaia = Roughly one per cent of the stars in the Milky Way

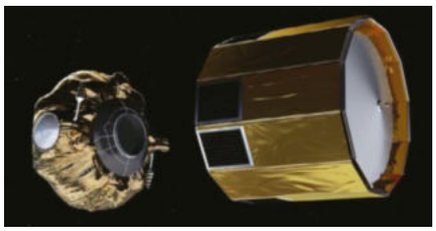
HOW TO...

launch to a Lagrange point

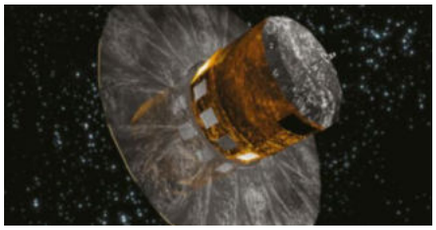
1 Achieving liftoff
In order to launch a space observatory, a powerful rocket is needed in order to produce enough thrust to escape the Earth's gravity. In the case of Gaia, the Russian Soyuz rocket was the instigator of the departure.

2 Stuck in low-Earth orbit
After roughly nine minutes, the Fregat-Gaia duo separated from Soyuz and placed into low-Earth parking orbit. The Fregat rockets will eventually launch the spacecraft, in this case Gaia, towards L2 after one orbit of the Earth.

3 Next stop, L2
After one orbit, Fregat re-ignites and sends the observatory into a hyperbolic L2 transfer trajectory. After a second Fregat burn the space observatory detaches and Fregat is sent off in a different direction to avoid re-contact.



4 Orbit insertion
It takes about three weeks to reach Lagrange point 2, which is about 1.5 million kilometres (932,057 miles) from Earth. In approach to L2, the sunshields and solar arrays are deployed, and communications are made.



SPACEX'S NEW ROCKET BREAKS RECORDS

The latest Falcon 9 model, the Block 5, has recently undergone its first of many spaceflights

The 11 May 2018 was not just the launch of the Bangabandhu-1 satellite, it also marked a memorable day for SpaceX, and could prove to be a milestone in their continuation to create sustainable spaceflight. SpaceX's Falcon 9 Block 5 is the new-and-improved model, and the private space company has gone as far as to say that this rocket is capable of at least ten blast-offs into Earth orbit. By taking into account all its failures, Elon Musk and SpaceX have created a rocket that would be remarkable for rapid reusability while maintaining an exceedingly good standard of reliability with each and every launch.

Bangladesh's first geostationary communication satellite sat on top of a rocket that has learned from its predecessors' mistakes. For instance, in September 2016 a Falcon 9 was scheduled to launch Amos-6, a communications satellite for the Israeli-based company Spacecom. However, during the routine engine test just two days before launch, the Falcon 9 rocket and Amos-6 exploded in an incredible fireball. The source of the trouble was the Composite Overwrapped Pressure Vessels, or COPVs. These vessels store helium to pressurise the propellant tanks in the launcher's second stage, and in the case of this explosion, the liquid oxygen in the upper-stage tank got trapped between the COPV's overwrap and liner before catching fire. The ignition was most probably caused by friction, but there could have been from other mechanisms in play, but the result ended in disappointment.

To improve on this, Musk and his team put a lot of work into redesigning the pressure vessels. "This is by far the most advanced pressure vessel ever developed by humanity," said Musk at a recent briefing with reporters prior to the Falcon 9 Block 5 launch. "It's nuts. I've personally gone over the design; I can't count how many times. The top engineering minds at SpaceX have agonised over this... I think we are in a good situation."

Despite the fact it is named 'Block 5', this is the sixth instalment of the Falcon 9 series. This rocket is much more powerful than its original model while also promoting revolutionary reusability. In comparison to the original model that launched in 2010, Block 5 is roughly twice as powerful, with each of the nine Merlin engines providing a thrust at sea level of 190,000 pound-force, while the single vacuum-optimised Merlin engine on its second stage contributed 220,000 pound-force.

During the briefing prior to Block 5's launch, Musk also emphasised how its new design will now make it capable of at least ten flights, if not more. With no refurbishment between flights, all that is needed is to gas up the tank again and it is good to go. But will there be a Falcon 9 Block 6? The answer to that question is no. Musk made it clear that although there might be some minor improvements, the Block 5 will be the final platform, allowing them to devote more time to other projects. Projects that could possibly take us to Mars, perhaps?

SpaceX's Falcon 9 Block 5 should be capable of at least ten spaceflights

Tim Peake & NASA's finest reveal...

"OUR MOST DANGEROUS MISSIONS"

It's important to protect astronauts from the harshness of space, but problems with technology can throw a spanner in the works

Technology often goes wrong here on Earth, but when it malfunctions or develops a fault in space, the situation is usually far more serious. In this third and final part of our series we look at how engines can fail, heat shields can be destroyed and how miscommunication or unfulfilled expectations can make problems worse.

We also take a look at two of the most tragic events in spaceflight history: the Challenger and Columbia disasters. With 14 deaths between them they show just how dangerous space travel can be. They are also proof of the courage, bravery and heroic nature of those men and women who have ventured forth on some of the greatest adventures that humankind has ever witnessed.

PART 3 OF 3

The Soyuz capsules are small spaces, but the chance of them being hit by space debris is much smaller than with the ISS

"You plan a safe move or hunker down and duck"

Jonathan McDowell of the Harvard-Smithsonian Center for Astrophysics explains the dangers posed to Space Station astronauts by orbiting junk

What happened?

In June 2011 a piece of space junk flew past the International Space Station at 29,000 miles per hour. While it missed the ISS by 335 metres (1,099 feet) it was spotted too late to perform any manoeuvres, and so the six crew members had to seek safety in the two docked Soyuz capsules until the danger had passed. The probability of a hit was calculated at 1 in 360 – far below the 1 in 10,000 risk at which NASA usually calls for precautions.

What mission were they on?

The incident took place during the Expedition 28 mission. Russian cosmonaut and ISS commander Andrei Borisenko was with flight engineers Aleksandr Samokutyayev and Sergey Volkov, as well as NASA astronauts Mike Fossum and Ron Garan, and Japanese Aerospace Exploration Agency astronaut Satoshi Furukawa.

"In the US, the military is responsible for tracking space junk, so the US strategic command goes through a catalogue of 18,000 objects every day to work out how close each piece is going to get to the International Space Station. They are almost all false positives because they cannot tell for sure whether a piece of debris will hit: the junk is generally calculated as being somewhere between a mile and zero, but it's usually half a mile or so.

"Because it might be zero, however, alerts are issued, and it means a lot of work goes on to improve the tracking and prediction capabilities. The more accurate they are the fewer alarms there will be, and as long as there is enough warning action can be taken. With enough time, NASA can fire the rocket engines on one of the cargo ships to boost the orbit slightly. They can also change the timing of the orbit so that all that's needed is to be in a different place at a time when a piece of space junk is going to strike.

"But it's also a little more complicated than that because you don't want to move the ISS to a place where some other piece of space junk will collide with it instead. It's certainly not a case of spotting something with five minutes to go and saying: 'alarm, alarm! We've got a close conjunction so we're going to move the station.' It takes a day or so to figure out. In the case of 2011, there was no time. The warning came too late so they had to go to a red conjunction, and this indicates that a piece of debris is close enough to pose a threat."

The International Space Station is at risk of being hit by space junk, and scientists have warned the amount is at tipping point

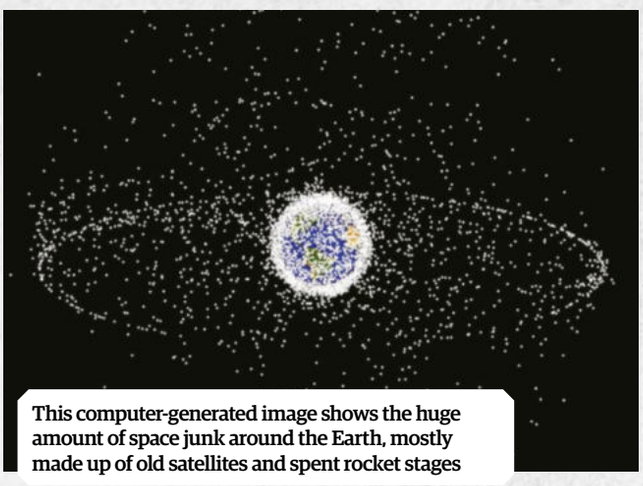
"What they do – as they did in this case – is tell the astronauts, ten minutes before the close approach, to go to their rescue ships and close the hatch. In this case it was the Soyuz ferry ships, and they provide a safe compartment if the ISS happened to get holed on this occasion. Now, if the ferry ship happens to be the thing that gets holed, well, it's a bad day. But the idea is that the Soyuz are much smaller targets.

"From that point the astronauts could just ride it out, and Houston calls up and says: 'Ok, it's passed, no worries, go back into the space station.' So those are basically the two scenarios: you either have enough time to plan a safe move of the orbit or you hunker down and duck. In 2011, this was a case of ducking and hoping their head would still be attached an hour and a half from now.

"If the danger to the ISS was real, however, the capsules can allow for a quick undock, returning the astronauts to Earth. There's also a little bit of micrometeorite protection on the space station, so really small pieces will get soaked up. But anything big and there's a problem.

"For example, a classic case of a space collision happened in 2009 when two communication satellites smashed into each other. One of them was an old, dead Russian military device while the other was an active US commercial Iridium satellite. That was two half-ton satellites smashing into each other at 42,117 kilometres (26,170 miles) per hour, and the energy in the collision was about 50 gigajoules. Now, a megajoule is the energy you get if you were hit by a one-ton truck travelling at a 160 kilometres (100 miles) an hour. And this collision is 54,000-times the energy of that. That's the sort of energy we're talking about in a space junk collision, so there's not a lot you can do except not get hit.

"It can happen, though. In 1997, an unmanned supply vessel crashed into the Mir space station, and despite it being at a low speed of probably a few miles an hour, it was enough to hole the module. The astronauts on board heard a hissing sound and a bang, and they had to immediately close of the door to the module. It wasn't catastrophic, but it was certainly near-fatal. When you consider that some random piece of space junk will be going at tens of thousands of miles an hour then you realise how screwed you'd be. We could get to a point where it's not possible to have something like the ISS because there's just too much space junk."



This computer-generated image shows the huge amount of space junk around the Earth, mostly made up of old satellites and spent rocket stages

The dangers of falling debris

Humans have been lauching things into space ever since Sputnik's launch on 4 October 1957. As a result there are an estimated 500,000 pieces of space debris that are larger than the size of a marble, and over 20,000 pieces are larger than a cricket ball, orbiting the Earth at around 17,500 miles (28,164 kilometres) per hour. While these pose threats to satellites and space stations while in orbit, some can fall back towards Earth with the potential to cause accidents.

In January 1997, a woman in Tulsa, Oklahoma was unexpectedly struck on the head by a piece of debris later identified as part of a Delta II booster. Luckily it was a small, lightweight piece, so she was startled, but unharmed.

In the 1960s, many debris finds were attributed to UFO phenomenon. A mysterious titanium sphere was found in Merkanooka, Western Australia. Dubbed the Merkanooka ball, the metal sphere was later identified as a tank used for drinking water in the Gemini V spacecraft.

"The ground wasn't seeing what we were seeing"

Mike Mullane explains how the Space Shuttle Atlantis had a close call in 1988 when its heat shielding was substantially damaged during liftoff

The crew of STS-27 were, clockwise starting top left, William Shepherd, Mike Mullane, Jerry Ross, Robert Gibson and Guy Gardner

What happened?

Just 85 seconds after launch, Space Shuttle Atlantis was struck by a piece of insulation which had come off the right-hand solid rocket booster nose cap. More than 700 heat shield tiles were damaged, and one tile was missing entirely.

What mission were they on?

The problem struck on STS-27, which was only the third flight of Space Shuttle Atlantis and launched on 2 December 1988.

"We never saw anything happen during launch. We only found out there was a potential problem when mission control informed us later, saying they had looked at the cameras and had seen something detach from the shuttle. We know now that a piece of the nose of the rocket side booster had broken off and flown back, hitting the heat shield tiles. But all we were concerned about at the time was how much damage had been caused and what effect that would have on the mission.

"Mission control told us to use the space shuttle's robot arm to take a look at the craft's exterior. The arm had a camera on the end of it and, as the robot arm operator, I was to bend this thing over and take a look at the heat shield. When we looked, we could see that there appeared to be significant damage to the shuttle.

"This leapt out at us because those tiles are normally black. They have a very thin outer black coating, but this had been stripped off. Underneath is Styrofoam and very white – and this clearly revealed itself. We could see white streaks everywhere which showed the extent of the damage, and it trailed beyond what the camera could view. Hundreds of tiles had been damaged.

"There was one tile that was missing in a very high temperature point. It would probably see about 2,500 degrees Fahrenheit [1,371 degrees Celsius] on re-entry. It was certainly cause for concern, and we told the ground what we were seeing and that it looked serious. We worried that the leading edges of the wing would be affected because they're subjected to intense heat right on re-entry through Earth's atmosphere.

"But it turned out that the ground wasn't seeing what we were seeing. Since we were on a military mission there was a fear that the images would reveal something secret, and the military did not want any of the data on the video going down to the ground without first going through them. Due to that there was some apparent degradation of the video as it passed through to mission control. Yet we were unaware of this convoluted path.

"I only heard about all of this after we got back and, in fairness to mission control, they were just not able to see the severity of the damage that we were seeing. But on board, we were a little bit confused initially by mission control's reaction. We were surprised that they felt so confident – usually mission control thinks there's a serious problem and looks into it. So the fact that they didn't follow up with surveys and other data-gathering exercises was kind of surprising to us.

"We thought that mission control was not doing what we expected them to do, and so when we were re-entering I think all of us had some concern in the back of our mind about the damage we had seen.

"I know the commander told me later that he was watching the gauge that showed the levels of deflection in the elevons at the rear of Atlantis' wings. He was looking for signs that one wing was moving left because it was coming apart. When we got back safely and the problem could be looked at properly, there was disbelief. It was much worse than we expected. We were lucky, but miscommunication and poor quality pictures had proven to be problematic."

> "When we were re-entering I think all of us had some concern in the back of our mind"
> **Mike Mullane**

Did you know?

Riding Rockets: The Outrageous Tales Of A Space Shuttle Astronaut recounts Mullane's space career

A clearly damaged space shuttle comes in to land at Edwards Air Force Base in California

"I felt sick to my stomach. I still feel sick to my stomach"

All seven crew members of mission STS-51L died during the tenth flight of Space Shuttle Challenger, halting the shuttle program for 32 months

What happened?

Just 73 seconds after liftoff, following delays which had postponed the launch, Space Shuttle Challenger broke apart and descended into the Atlantic Ocean. It was one of the worst disasters in NASA's history, and the first disaster of its Space Shuttle program. Sadly, all seven crew members were killed.

What mission were they on?

Mission STS-51L, which had originally been due to launch on 22 January 1986, but was eventually moved back following numerous other postponements to 28 January.

"I felt sick to my stomach. I still feel sick to my stomach," said Brian Ballard, the editor of *The Crimson Review* at Concord High School. Earlier that day – 28 January 1986 – he had been with thousands of tourists, NASA officials and scores of journalists for the launch of the Space Shuttle Challenger. But 73 seconds after liftoff from the pad at the Kennedy Space Center at Cape Canaveral, Florida, things began to go terribly wrong.

It was 16:39:13 UTC and Challenger was high in the air. As is so often the case with such a launch, it was a mesmerising sight, the spacecraft soaring majestically on a column of fire and smoke with everything having apparently gone so well. "It has cleared the tower," said mission narrator Steve Nesbitt. "Three engines running normally." Then, as a good number of viewers watched at home on their television sets (with lots of children tuning in at school), disaster struck and shocked the world.

"Things started flying around and spinning around, and I heard some 'Ohs' and 'Ahs', and at that moment I knew something was wrong," Ballard told the *New York Times* at the time. Indeed, CNN correspondent Tom Mintier had only just announced to viewers: "This morning it looked as though they were not going to be able to get off," when he was forced into silence. Seconds passed as images appeared to show an explosion, with debris raining down, but few watching were quite sure what to make of it. "Flight controllers are looking very carefully at the situation," Nesbitt said. "Obviously a major malfunction."

At that point, its thought that the crew were still alive. There were seven members on board, including mission commander Francis Scobee, pilot Michael Smith, mission specialists Judith Resnik, Ronald McNair and Ellison Onizuka, and payload specialist Gregory Jarvis. There was also payload specialist Christa McAuliffe, a 37-year-old high school teacher from Concord, New Hampshire who had beaten more than 11,000 applicants in the NASA Teacher in Space Project.

The main engine exhaust, solid rocket boost plume and a ball of gas from the external tank were visible in the seconds following the accident

McAuliffe was set to be the first US citizen in space. Instead, Challenger had broken up in the air. O-ring seals used in a joint within the right solid rocket booster were later found to have failed at liftoff, caused in large part by the unusually cold conditions felt that bitterly freezing winter's morning. They had never been tested at such low temperatures and they had become stiff and unable to seal the joint. As a seal opened and exhaust leaked, the hull of the cold external tank which was filled with liquid oxygen and hydrogen ended up becoming covered with the stuff. The tank ruptured and aerodynamic forces pulled the shuttle apart. A huge fireball resulted.

The crew compartment, however, remained intact. It sailed skywards, reaching an altitude of 19.8 kilometres (12.3 miles) before free-falling the same distance, two minutes and 45 seconds after the shuttle had started to break up. It plunged deep into the Atlantic Ocean and all seven on board died, despite immediate efforts to send recovery ships to the sea in the hope of recovering the crew compartment. Divers from the USS Preserver eventually located the crushed and fragmented crew compartment on the ocean floor about six weeks later on 7 March 1986. The discovery was announced to the media two days later.

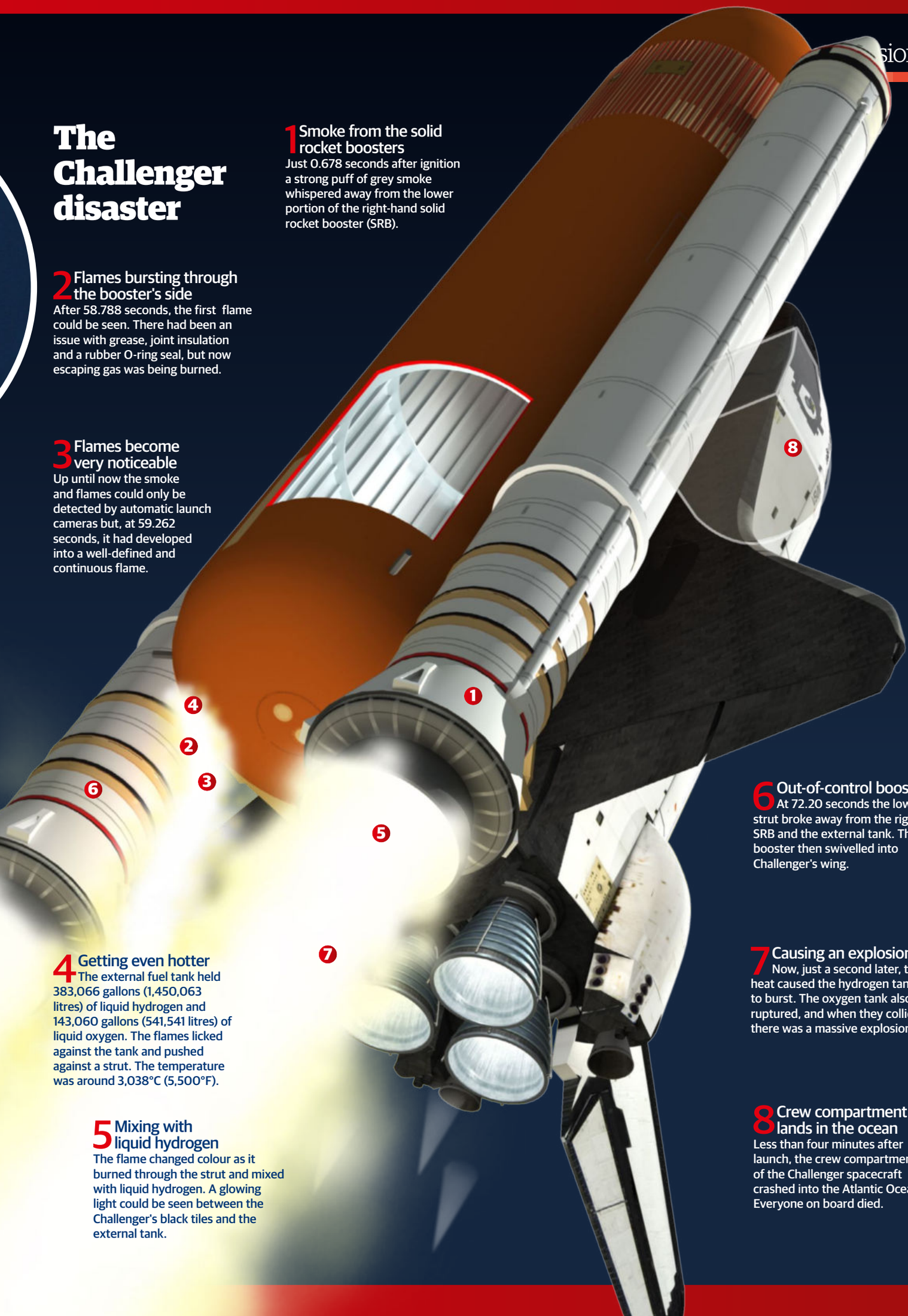
An investigation then found that NASA knew extreme temperatures would affect the O-rings. Indeed, engineer Bob Ebeling was among five people eager to ground Challenger the previous day. Following fruitless arguments, he told his wife that night, "It's going to blow up". Guilt ate away at Ebeling from that day, even though he was not the decision maker and in no way to blame. It was a true tragedy, and there is no doubt that it altered NASA's space programme forever.

"We will never forget them, nor the last time we saw them, this morning, as they prepared for their journey and waved goodbye and 'slipped the surly bonds of Earth' to 'touch the face of God'"

Ronald Reagan, 28 January 1986

The STS-51L Challenger crew, clockwise from top left: Ellison S. Onizuka, Sharon Christa McAuliffe, Gregory Jarvis, Judith A. Resnik, Ronald E. McNair, Francis R. Scobee, Michael J. Smith

The Challenger disaster



1 Smoke from the solid rocket boosters
Just 0.678 seconds after ignition a strong puff of grey smoke whispered away from the lower portion of the right-hand solid rocket booster (SRB).

2 Flames bursting through the booster's side
After 58.788 seconds, the first flame could be seen. There had been an issue with grease, joint insulation and a rubber O-ring seal, but now escaping gas was being burned.

3 Flames become very noticeable
Up until now the smoke and flames could only be detected by automatic launch cameras but, at 59.262 seconds, it had developed into a well-defined and continuous flame.

4 Getting even hotter
The external fuel tank held 383,066 gallons (1,450,063 litres) of liquid hydrogen and 143,060 gallons (541,541 litres) of liquid oxygen. The flames licked against the tank and pushed against a strut. The temperature was around 3,038°C (5,500°F).

5 Mixing with liquid hydrogen
The flame changed colour as it burned through the strut and mixed with liquid hydrogen. A glowing light could be seen between the Challenger's black tiles and the external tank.

6 Out-of-control booster
At 72.20 seconds the lower strut broke away from the right SRB and the external tank. The booster then swivelled into Challenger's wing.

7 Causing an explosion
Now, just a second later, the heat caused the hydrogen tank to burst. The oxygen tank also ruptured, and when they collided there was a massive explosion.

8 Crew compartment lands in the ocean
Less than four minutes after launch, the crew compartment of the Challenger spacecraft crashed into the Atlantic Ocean. Everyone on board died.

"I wasn't even aware that the main chute had opened"

British astronaut Tim Peake momentarily feared his main parachute had failed to open as he made his re-entry to Earth

A smiling Tim Peake is carried to a medical tent following the landing near Zhezkazgan, Kazakhstan

What happened?

Travelling back from the ISS in the small Soyuz capsule with his crew mates, Tim Peake suddenly realised that he hadn't felt the main parachute opening, causing him to momentarily worry.

What mission were they on?

Peake was returning home from Expedition 46/47 on 18 June 2016.

"Working and living on the ISS is the best place you could possibly wish, as a professional, to be. You are in an environment where you are so well supported; you are very aware you are doing absolute cutting-edge technology. The descent is a really exciting ride. In actual fact the undocking is fairly uneventful, and the first couple of orbits in space are uneventful. You're just waiting for that de-orbit burn.

"And it's from the de-orbit burn onwards that things get really exciting. The de-orbit burn is quite a gentle burn, so it's not like you feel a huge amount of deceleration during that. But if things are going to go wrong on landing, they will probably go wrong during that de-orbit burn. It's somewhere where you are very, very aware of controlling all the systems and making sure everything is functioning normally, because if that burn goes long or if goes short, you're going to miss your target, and your re-entry profile will be very different from what it should be.

"But I was aware, having spoken to lots of astronauts about the descent, what to expect. Separation was very dynamic and again, in my previous military career I have had the pleasure of flying some Russian helicopters, so I'm very familiar with Russian engineering and Russian technology, and it's robust. It works very well but it's very solid, and when a solid spacecraft is designed to break into three parts, it doesn't do it quietly. It does it with a number of pyrotechnic bolts that all go off one after the other, sounding like a very heavy machine gun, and the spacecraft really does blow itself apart, which is really quite exciting to be in the centre of. And these pyrotechnic bolts are only a few millimetres of metal away from your ear when they go off.

"From then on the spacecraft is tumbling in a fairly controlled manner, just waiting to enter the Earth's atmosphere. It's a great thing being sat next to the window because you're able to look out, and at that point I started seeing sparks and flames coming off because all of the multilayer insulation around the spacecraft was burning away. So it's very exciting to see that, and again I was warned about that and told that was absolutely normal – [we] expect to see flames coming past the window, waiting for the gs to build up, [knowing we] haven't really entered the Earth's atmosphere.

"But you're down to almost 100 kilometres (62 miles). I looked out of the window and, having spent six months watching planet Earth from 400 kilometres (249 miles) in a very controlled altitude, to look out of the window and see Earth approaching at 100 kilometres (62 miles) in what looked like a fairly uncontrolled altitude was really quite surprising. It really gave a very strong sensation that you are just falling back to the planet, and then the gs start to build up.

"The gs come on fairly slowly, so you get plenty of time to get used to that. But towards the end you are doing four or so gs, which after six months at zero gravity is quite a lot, so you're having to control your breathing and work on that. But the capsule gets very hot, extremely hot, and so you're working hard against the g, you're working hard against the heat; your visors are down and you don't have much ventilation inside. You're having to read the systems inside and check the spacecraft, and so there's an awful lot going on. And at the same time you're trying to memorise the experience.

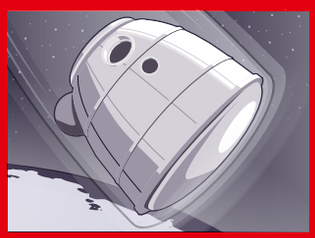
"It's a wonderful ride, and then probably the most dynamic part is when the parachute opens and you get about 20 seconds where the capsule is being completely flung around and you just have to really hold on and wait for it all to stop. I was told that it would stop with a big jolt as the main chute opened, but in our case it didn't. The main chute must have been a very gentle opening, so I wasn't even aware that the main chute had opened. And the clock was running, and I'm very aware of exactly what should happen and at exactly what time. The time had gone beyond the point at which the main chute had opened.

"So for a second I was concerned. I looked across at Yuri [Malenchenko]. He was just sitting there so relaxed and cool as he always is. So I thought if we didn't have a main parachute opened he wouldn't be looking as cool as that, so I was quite comfortable at that stage that we must be under the main canopy. And then you get a few moments of respite when you can gather your thoughts and get yourself ready for the landing."

The Soyuz spacecraft in which Tim Peake landed with fellow Expedition 46/47 crew members Tim Kopra and Yuri Malenchenko

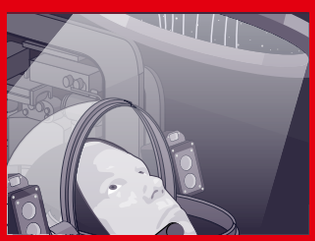
Shaky return

Peake believed Soyuz's main parachute hadn't opened on his return



Entering the atmosphere

Tim Peake returned to Earth in the Russian-built Soyuz TMA-19M descent module. It dropped through the atmosphere, which caused it to slow.

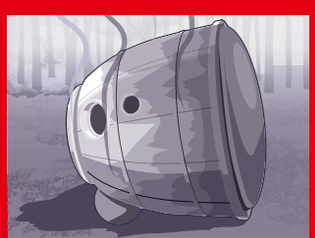


Watching the clock

The parachute cover jettisoned and the drogue chute opened, the drag causing Soyuz to swing. Tim waited for a jolt as the main chute opened. He didn't feel anything.

Feeling much relief

Concerned, he noted much time had passed. Thankfully, it turned out the main chute had opened on time, but gently. The heatshield was also jettisoned.



Making his landing

The main parachute slowed Soyuz down further. As the spacecraft got closer to the ground, small rocket engines slowed more and enabled a landing.

"Right at liftoff, we got several alerts"

How close the crew of STS-93 came to disaster still remains unknown, but astronaut Steven A. Hawley explains the moment engine controllers were disabled by an electrical short

What happened?

About five seconds after liftoff an electrical short disabled the centre engine's primary digital control units, along with the right engine's secondary digital control units. Meanwhile, a shortage of fuel during the ascent of STS-93 was traced to a huge hydrogen leak. This could have caused the engine to dangerously overheat.

What mission were they on?

Hawley was on STS-93 on a primary mission to deploy the Advanced X-ray Astrophysics Facility (now known as the Chandra X-ray Observatory).

"We had scrubbed two previous attempts at launching STS-93: the first was on 20 July 1999 due to a data spike in hydrogen pressure just before main engine ignition, and the second was on 22 July when there was a lightning storm. But a day later, we were ready to go.

"By this point, Columbia had flown 25 missions, but right at liftoff we got several alerts that, taken together, suggested an AC electrical short. Mission control had notified us right away that it was a short and that one of the consequences was loss of redundancy in the engine controllers on two Space Shuttle main engines (SSME). The loss of another controller on one of those engines would have shut down the SSME. No single-engine failure would result in a bailout.

"I was looking at our procedures for a contingency abort should we lose two engines, although I wasn't particularly worried about that really happening. In flight, I didn't think that was likely because the Shuttle systems are robust and I had a lot of confidence in their reliability. Of course I didn't know the cause of the AC short so, in retrospect, another AC short was probably more likely than I had assumed at the time.

"At liftoff, however, another failure had happened which we didn't know about at the time. A gold pin had been dislodged from a liquid oxygen tank (LOX) post during the main engine ignition sequence and, as it was violently ejected, it struck the inner surface of the engine nozzle. This damaged several cooling tubes containing hydrogen, and the damage allowed hydrogen to leak during ascent (it was leaking 1.5 kilograms [3.3 pounds] of hydrogen every second). Consequently we had a low-level cutoff of the three SSMEs for only the second time in Space Shuttle program history.

"I could tell immediately from the onboard displays that we were lower than we were supposed to be at Main Engine cutoff (MECO). However, I knew they were high enough to be able to do the mission. I wondered why we were short, but I didn't dwell on it since it didn't appear to have any mission impact. The digital control units that were not shorted operated the centre and right engines.

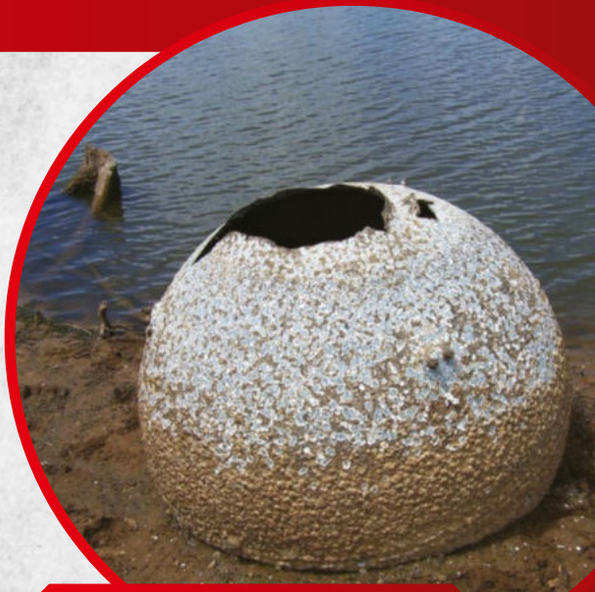
"But in a day or so, the ground was able to tell us about the fuel leak. One interesting consequence of the AC short was that the secondary controller (and I don't recall now which engine it was) had a bias in the pressure transducer which controlled the mixture ratio in a way that actually used less fuel than planned.

"Without the AC short the fuel leak would probably have had a greater effect. As it was, we achieved our intended orbit and completed the mission as planned. After the flight I found out that the ground controllers were aware of the engine performance issues during ascent, but we weren't on board. Poorly routed wiring rubbing on an exposed screw head was found to be the cause of the electrical short. They did a good job of figuring it out."

Steve Hawley flew on five Space Shuttle flights for NASA, starting with STS-41D Discovery in 1984 and ending with STS-93 Columbia which landed on 27 July 1999

"It is easy to overlook the dangers of travel by rocket"

The break-up of the Space Shuttle Columbia claimed the lives of the seven astronauts on board in 2003



This aluminium cryogenic liquid storage tank from Columbia was among the many pieces of debris recovered from the disaster

What happened?

About 82 seconds after launch, a large piece of foam broke off from the external tank, damaging the thermal protection system of the orbiter's left wing. Upon re-entry the damaged wing slowly overheated and came apart, causing the shuttle to disintegrate.

What mission were they on?

STS-107, Columbia's 28th mission, orbited for 15 days, 22 hours, 20 minutes and 32 seconds conducting a range of experiments before re-entry.

Just 17 years after the Challenger disaster, NASA suffered its second fatal accident of its Space Shuttle program. This one concerned Columbia, the first space-rated orbiter in the fleet. During the launch of its 28th mission, STS-107, on 16 January 2003, it suffered serious damage to its left wing and unfortunately this would later prove fatal.

Video evidence later revealed that a large piece of insulating foam had detached from the shuttle's external tank and had struck the orbiter's left wing. This punched a hole into the reinforced carbon-carbon panels along the left wing's leading edge, damaging the thermal protection of the orbiter.

Almost 16 days later, on 1 February 2003, the crew began their journey back to Earth after what had been a successful science mission. But their fate had already been sealed. During re-entry the damaged wing allowed superheated atmospheric gases to penetrate and destroy its internal structure, causing the spacecraft to destabilise and break apart.

270 seonds after re-entry, Columbia's wing was showing signs of strain but at mission control re-entry appeared normal. But Columbia was exposed to temperatures of more than 1,540 degrees Celsius (2,800 degrees Fahrenheit). 555 seconds after entering the atmosphere pieces of the orbiter were being shed, and a series of bright flashes followed. When contact was made with commander Rick Husband only one word – "Roger" – was clear. Just 16 minutes from its scheduled landing at the Kennedy Space Center, Columbia disintegrated around 61 kilometres (38 miles) above Texas, and sadly all on board were lost.

"The breakup of the crew module and the crew's subsequent exposure to hypersonic entry conditions was not survivable by any currently existing capability," a subsequent report said. "The ascent and entry suit had no performance requirements for occupant protection from thermal events." Some 30 recommendations were made for improving equipment and training, including seat restraints and more suitable helmets.

Along with Husband, those who were lost were pilot William McCool, payload commander Michael Anderson, payload specialist Ilan Ramon (Israel's first astronaut), and mission specialists Kalpana Chawla, David Brown and Laurel Clark. For days debris rained down on parts of Texas.

"In an age when space flight has come to seem almost routine, it is easy to overlook the dangers of travel by rocket, and the difficulties of navigating the fierce outer atmosphere of the Earth," said President George W. Bush on the day of the disaster. "These astronauts knew the dangers, and they faced them willingly, knowing they had a high and noble purpose in life. The cause [for] which they died will continue. Mankind is led into the darkness beyond our world by the inspiration of discovery and the longing to understand. Our journey into space will go on."

> "This is indeed a tragic day for the NASA family, for the families of the astronauts who flew on STS-107, and likewise is tragic for the nation"
>
> **NASA administrator Sean O'Keefe**

The crew of STS-107, left to right, David M. Brown, Rick D. Husband, Laurel Clark, Kalpana Chawla, Michael P. Anderson, William C. McCool and Ilan Ramon

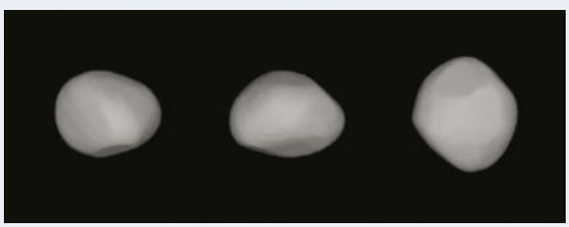
STARGAZER

GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

In this issue...

What's in the sky?

21 JUL
Asteroid 88 Thisbe reaches opposition in Sagittarius, glowing at a magnitude of 9.7



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25 JUL
Conjunction between the Moon and Saturn in Sagittarius

25 JUL
The Moon and Saturn make a close approach, passing within 1°59' of each other in Sagittarius

26 JUL
The Capricornids reach their peak of five meteors per hour

29 JUL
The Delta-Aquarids reach their peak of 20 meteors per hour

2 AUG
The Alpha-Capricornids reach their peak of five meteors per hour

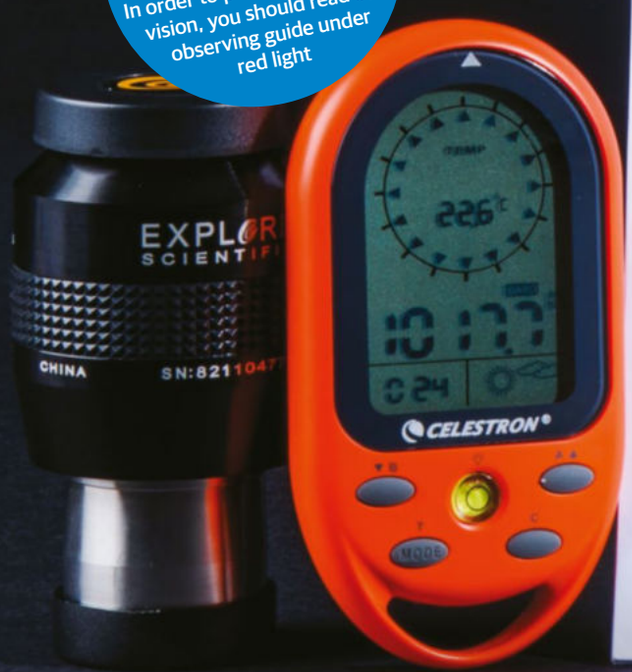
6 AUG
The Tau-Aquarids reach their peak of eight meteors per hour

© NASA/ESA ESO/S. Guisard

14 AUG
Globular cluster Messier 15 is well placed for observation in Pegasus

15 AUG
Venus reaches dichotomy in the evening sky, where it will be at half phase

Red light friendly
In order to preserve your night vision, you should read our observing guide under red light



Jargon buster

Conjunction
A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)
Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)
This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude
An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition
When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation
When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

21 JUL
Conjunction between the Moon and Jupiter in Libra

21 JUL
The Kappa-Cygnids reach their peak of five meteors per hour

21 JUL
The Moon and Jupiter make a close approach, passing within 4°13' of each other in Libra

27 JUL
Mars reaches opposition in Capricornus, shining at magnitude -2.8


© ESO/S. Guisard

27 JUL
Total lunar eclipse visible from parts of Europe, Asia, Antarctica, Australia and Africa

11 AUG
Partial solar eclipse visible from Russia, Canada, Greenland, China, Norway, Mongolia, Svalbard and parts of the UK

13 AUG
The Perseids reach their peak of 80 meteors per hour

14 AUG
Conjunction between the Moon and Venus in Virgo


© NASA/ESA

15 AUG
Globular cluster Messier 2 is well placed for observation in Aquarius

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

STARGAZER

Moon calendar

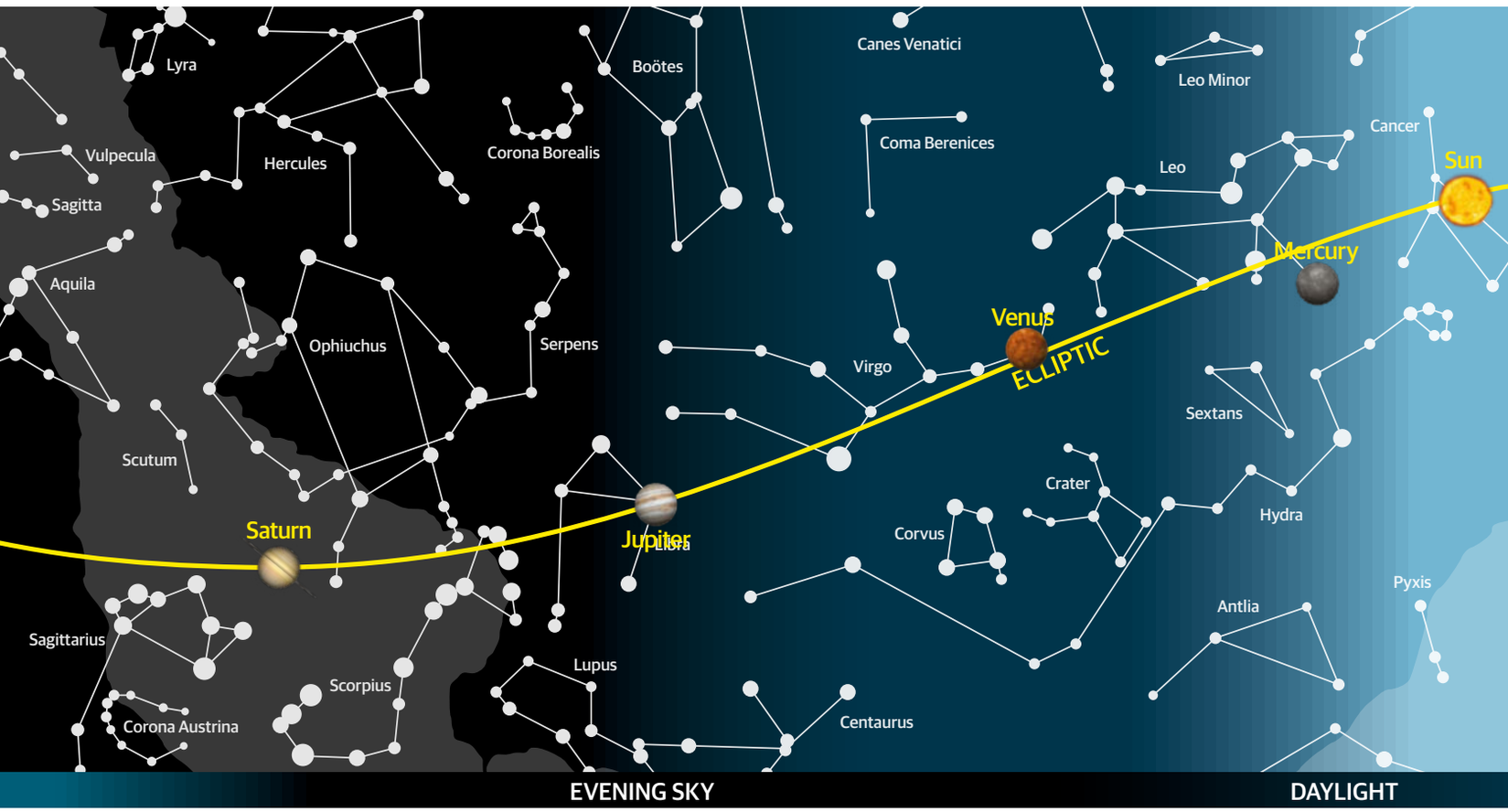
* The Moon does not pass meridian on 26 July

19 JUL FQ 49.3% 00:10 --:--	**20 JUL** 59.9% 00:32 14:16	**21 JUL** 69.9% 00:56 15:24	**22 JUL** 78.8% 01:22 16:31			
23 JUL 86.4% 01:51 17:34	**24 JUL** 92.4% 02:25 18:32	**25 JUL** 96.8% 03:05 19:24	**26 JUL** --:-*% 03:52 20:10	**27 JUL** FM 99.3% 04:45 20:49	**28 JUL** 100% 05:43 21:22	**29 JUL** 98.7% 06:45 21:49
30 JUL 95.6% 07:49 22:14	**31 JUL** 90.6% 08:55 22:36	**1 AUG** 83.9% 10:01 22:57	**2 AUG** 75.8% 11:09 23:18	**3 AUG** 66.3% 12:18 23:40	**4 AUG** TQ 55.8% 13:29 --:--	**5 AUG** 44.7% 00:05 14:43
6 AUG 33.5% 00:35 15:57	**7 AUG** 22.8% 01:11 17:10	**8 AUG** 13.3% 01:57 18:19	**9 AUG** 6.0% 02:55 19:18	**10 AUG** 1.4% 04:05 20:07	**11 AUG** NM 0.0% 05:24 20:47	**12 AUG** 2.0% 06:46 21:19
13 AUG 6.9% 08:09 21:47	**14 AUG** 14.3% 09:29 22:12	**15 AUG** 23.4% 10:46 22:35	**16 AUG** 33.5% 12:00 23:59			

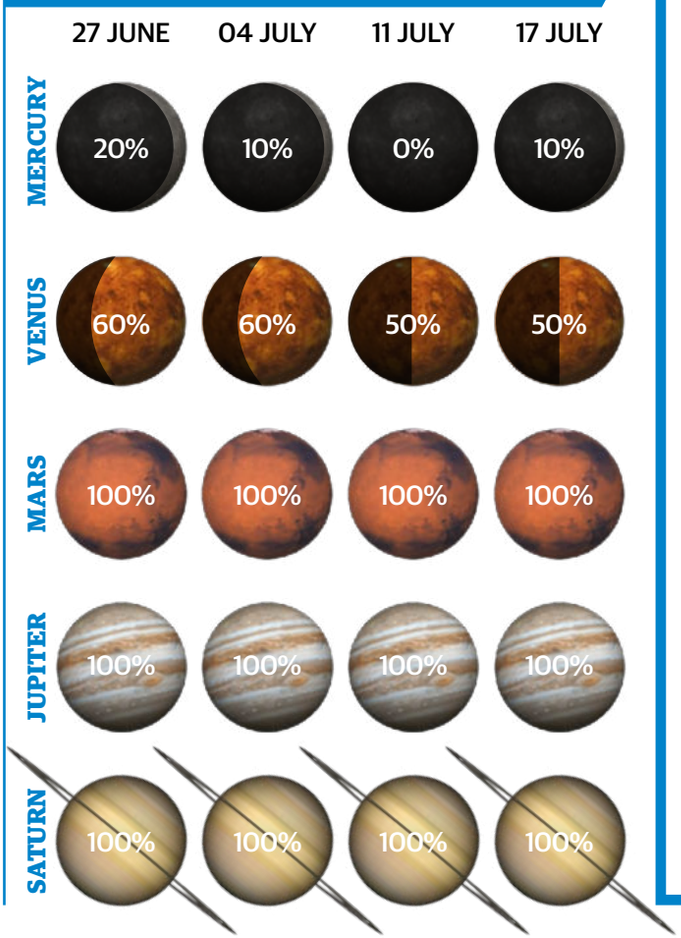
% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



Planet positions

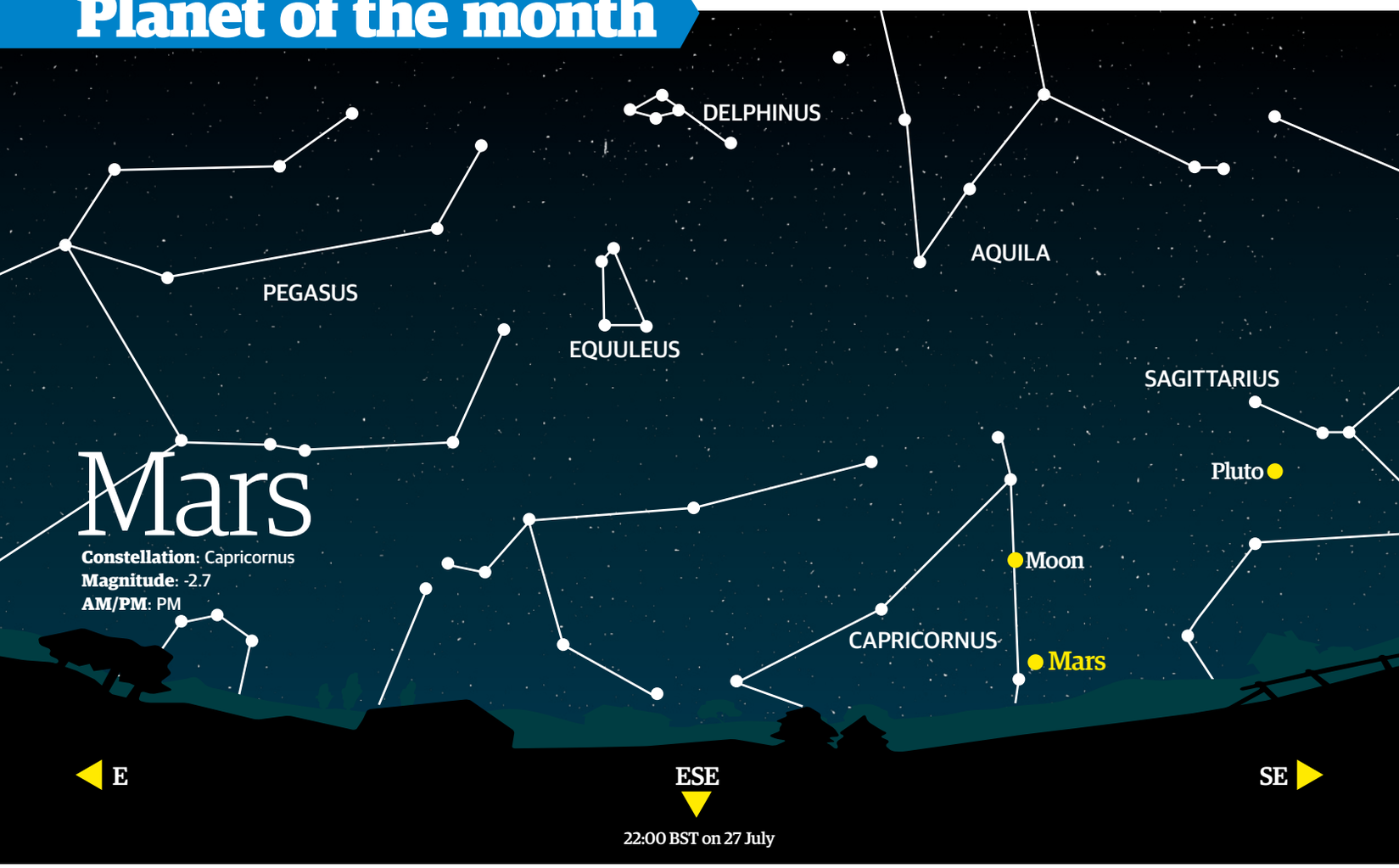
All rise and set times are given in BST

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	19 July	09h 36m 47s	+24° 27′ 01″	Leo	0.8	07:33	21:52
	26 July	09h 37m 32s	+10° 31′ 28″	Leo	1.6	07:23	21:19
	02 Aug	09h 28m 36s	+09° 59′ 07″	Leo	3.2	06:49	20:39
	07 Aug	09h 15m 03s	+13° 48′ 09″	Cancer	2.8	04:58	19:30
	16 Aug	08h 53m 13s	+13° 48′ 09″	Cancer	2.8	04:58	19:30
VENUS	19 July	10h 46m 09s	+08° 53′ 10″	Leo	-4.1	09:08	22:46
	26 July	11h 13m 41s	+05° 32′ 30″	Leo	-4.2	09:25	22:28
	02 Aug	11h 40m 08s	+02° 07′ 10″	Virgo	-4.2	09:41	22:10
	07 Aug	11h 58m 24s	-00° 09′ 08″	Virgo	-4.2	09:52	21:56
	16 Aug	12h 29m 59s	-04° 43′ 13″	Virgo	-4.3	10:10	21:30
MARS	19 July	20h 40m 21s	-24° 43′ 24″	Capricornus	-2.7	22:06	05:37
	26 July	20h 32m 56s	-25° 26′ 52″	Capricornus	-2.8	21:36	04:56
	02 Aug	20h 24m 56s	-26° 02′ 06″	Capricornus	-2.8	21:05	04:16
	07 Aug	20h 19m 28s	-26° 19′ 51″	Capricornus	-2.7	20:43	03:49
	16 Aug	20h 11m 31s	-26° 33′ 14″	Capricornus	-2.5	20:01	03:04
JUPITER	19 July	14h 44m 14s	-14° 49′ 13″	Libra	-2.2	15:08	00:44
	26 July	14h 45m 10s	-14° 55′ 23″	Libra	-2.2	14:42	00:17
	02 Aug	14h 46m 40s	-15° 03′ 59″	Libra	-2.1	14:17	23:46
	07 Aug	14h 48m 04s	-15° 11′ 33″	Libra	-2.1	13:59	23:27
	16 Aug	14h 51m 14s	-15° 27′ 51″	Libra	-2.0	13:28	22:54
SATURN	19 July	18h 17m 39s	-22° 33′ 28″	Sagittarius	0.1	19:28	03:30
	26 July	18h 15m 46s	-22° 35′ 04″	Sagittarius	0.2	18:59	03:00
	02 Aug	18h 14m 04s	-22° 36′ 34″	Sagittarius	0.2	18:30	02:31
	07 Aug	18h 13m 01s	-22° 37′ 35″	Sagittarius	0.2	18:09	02:10
	16 Aug	18h 11m 29s	-22° 39′ 17″	Sagittarius	0.3	17:33	01:33

This month's planets

The Red Planet reaches opposition this month and, providing you're in the right place, you'll be able to catch a wealth of its surface detail

Planet of the month



Mars

Constellation: Capricornus
Magnitude: -2.7
AM/PM: PM

Finally, after taking what has felt like an eternity, this month Mars reaches opposition! A planet is said to be at opposition when it is directly opposite the Sun in the sky, and because this opposition of Mars coincides with a relatively close approach of Mars to the Earth, astronomers all around the world have been looking forward to this month all year, impatient to see Mars looking bigger and brighter in the sky than it has for many years.

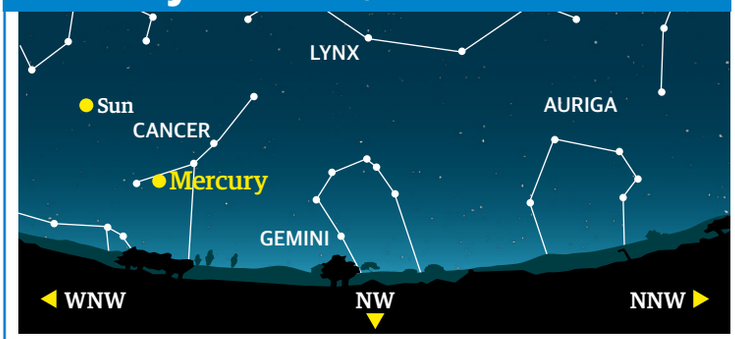
Unfortunately, because of its current position along the ecliptic in the constellation of Capricornus, Mars will not climb very high in the sky during this opposition. Instead it will hug the horizon, further diminishing our view. The sky won't get very dark either because of the time of year. All that means Mars won't appear as bright this July as you might expect a magnitude -2.7 object to appear.

Of course, if you really want to get the best out of this Martian opposition you could jump on a plane and head south to a country where Mars will shine at a higher altitude; stargazers in Australia and New Zealand will be able to see Mars blazing overhead – and in a dark, winter sky too. But wherever you will be, this month's sky absolutely belongs to Mars, and you should make a special effort to get out and see it. It will be easily visible to the naked eye from the back gardens of towns and cities, looking like a bright 'star' low in the southern sky.

However, if you can get away from all the clutter and streetlights out to somewhere in the countryside with a low, flat southern horizon and no light pollution, you will be hypnotised by the beauty of Mars. It will be a very striking sight, visible to the naked eye as soon as the sky starts to darken after sunset, and as twilight deepens it will get brighter and brighter until it dominates that part of the sky. Although it won't burn with the fiery red colour many people expect, it will be a very obvious orange colour, and if you have binoculars or a telescope they will enhance its beautiful colour tremendously.

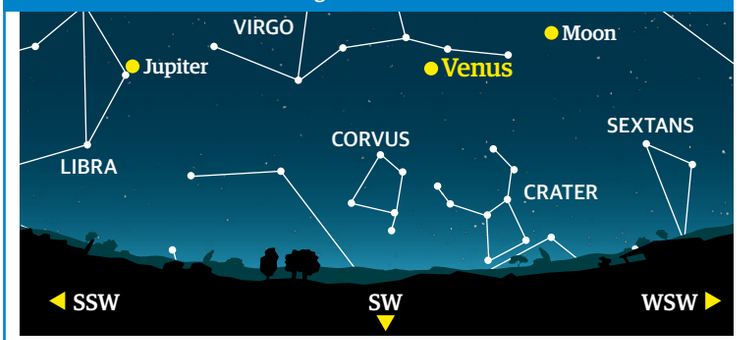
Although not as bright as others have been, this month's opposition will offer something quite amazing. On the evening of 27 July, the date of opposition, Mars will appear close to the Moon in the sky – at the same time as the next total lunar eclipse. Observers across much of the world will thrill at the sight of bright-orange Mars shining close to a copper- or blood-red Moon. In the UK Mars and the already fully eclipsed Moon will rise close together, making a stunning pairing in the late evening sky, and a great target for astrophotographers.

Mercury 18:30 BST on 15 August



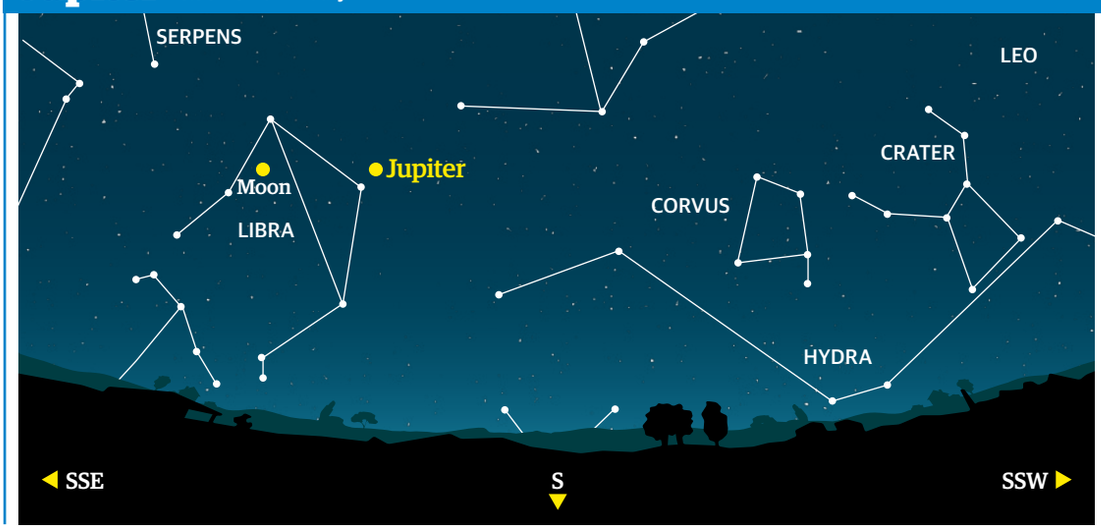
Constellation: Leo
Magnitude: 1.1
AM/PM: PM
At the start of our observing period, and for most of it, Mercury is too close to the Sun to be visible, setting at the same time. By mid-August the little world will still be a very challenging target, low in the bright sky before sunrise. With the Sun following this might be a month to enjoy looking at other planets.

Venus 18:30 BST on 15 August



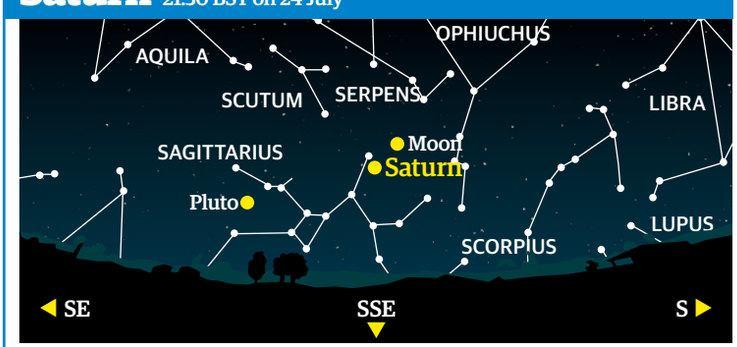
Constellation: Leo into Virgo
Magnitude: -4
AM/PM: PM
Setting only an hour after the Sun now, its magnitude of -4 means it is still is a naked-eye object, but shining at a low altitude against a bright twilight sky means it will not be as striking a sight as it was earlier in the year. The young Moon will pass above Venus between 13 and 15 August, with a beautiful crescent close on the 14th.

Jupiter 18:30 BST on 21 July



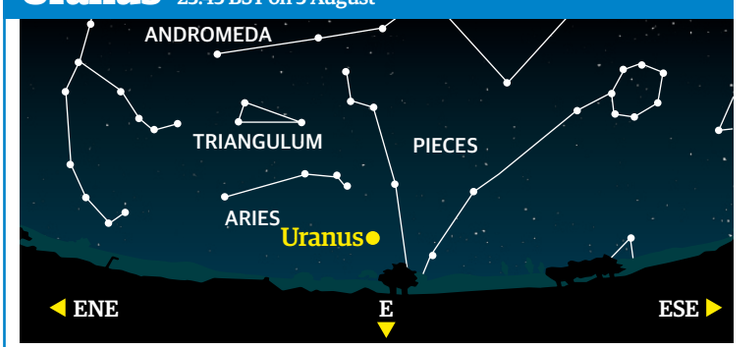
Constellation: Libra
Magnitude: -2.2
AM/PM: PM
At the start of our observing period Jupiter will be setting around half past midnight, and by mid-August will have set by 11pm, so its best nights are behind it. Still, shining at magnitude -2.2 it is a very easy naked-eye object, sandwiched between fainter Saturn to its far left and brighter Venus to its right, the enormous gas-giant world is still a very attractive sight. Look out for the waxing gibbous Moon to its upper right after sunset on 21 July, and to its upper left the following evening. Binoculars will show you its four largest moons, but you'll need a telescope to see its bands of cloud and famous Great Red Spot.

Saturn 21:30 BST on 24 July



Constellation: Sagittarius
Magnitude: 0.1
AM/PM: PM
Flanked by much brighter planets on either side, Saturn continues to glow low in the southern sky. The planet is visible from sunset through to the early hours. Binoculars will show you its largest moon, Titan, but you'll need a telescope to see its famous rings. The Moon will approach and then pass Saturn between 24 and 25 July.

Uranus 23:45 BST on 5 August



Constellation: Aries
Magnitude: 5.8
AM/PM: AM
At magnitude 5.8, Uranus will get easier to see as the month progresses. In mid-July it rises around midnight, but by mid-August is rising around 10pm, remaining visible through the evening until the sky brightens with the approach of dawn. The Moon passes beneath Uranus between 3 and 5 August.

Top tip!

Get to somewhere with a low and flat eastern horizon in plenty of time to watch the fully eclipsed Moon rising

Moon tour

The totally eclipsed Moon

What can you expect to see when our satellite is totally eclipsed on 27 July?

On the evening of 27 July, the Sun, Earth and Moon will align. Despite what you might read in the wackier corners of the internet, this isn't particularly rare, and no matter how many conspiracy theory fans post apocalyptic predictions on social media it will not cause any earthquakes or tidal waves, and no portals to alternative dimensions will rip open in the sky. All that will happen is that when the Moon moves into the shadow cast behind the Earth by the Sun, it will go dark for a while, before emerging from the shadow and returning to its normal appearance. This is called a total lunar eclipse, and amateur astronomers and star-gazers love watching them and look forward to them for months.

Even though lunar eclipses happen fairly often they are never boring, because every one is different. Although we know where the Moon will be in the sky at the time, what it will be close to and the precise timetable of the eclipse to the second, we can't know in advance exactly what the eclipsed Moon will look like. We know the Moon will appear darker in the sky while it is in Earth's shadow, but we can't predict just how dark. Some eclipses are darker than others: a fully eclipsed Moon can be bright enough that you can still see all its naked-eye features, or so dark it is almost impossible to see in the sky and looks like a hole cut out of the heavens. As for the colour, that's the greatest unknown – and the best surprise. Some totally eclipsed Moons are a bright orange colour and look like a Halloween lantern in the sky. Others are such a deep, brooding red-brown that they look like the Moon is shining through a glass of muddy water, or even blood.

Why are eclipses so different? For one thing, it depends on how far the Moon is going into the shadow cast by the Earth. If the Moon is going right through the middle of Earth's shadow, rather than just through its outer regions, we can know in advance that it will be dark during totality. However, its colour can't be known very accurately in advance because that's at least partially dictated by how much light reaches the Moon – after being bent around the Earth and refracted through its atmosphere – during the eclipse. What will the Moon look like on the evening of 27 July? We'll have to wait and see.

The eclipse begins at approximately 19:24 BST and will end almost four hours later when the Moon slips out of the shadow again. Unlike meteor showers, or displays of the northern lights, lunar eclipses are slow-moving events, so it's perfectly fine to watch them in stages, checking on their progress as they run their course.

One of the greatest joys of a total lunar eclipse is watching how the Moon's colour changes during it. At the start the shadow that begins to creep across the Moon is a dark-grey colour, almost like someone has shaded in part of the Moon with a pencil. As the shadow moves across the Moon covering more and more of it, it becomes more of a dark grey with touches of purple or lavender. By the time the Moon is half-eclipsed the shadow can have more of a pink tinge to it. At total eclipse the Moon can be as orange as a tangerine, as dirty brown as muddy water or as red as an apple. Every one is a surprise. And that's why so many sky-watchers look forward to them.

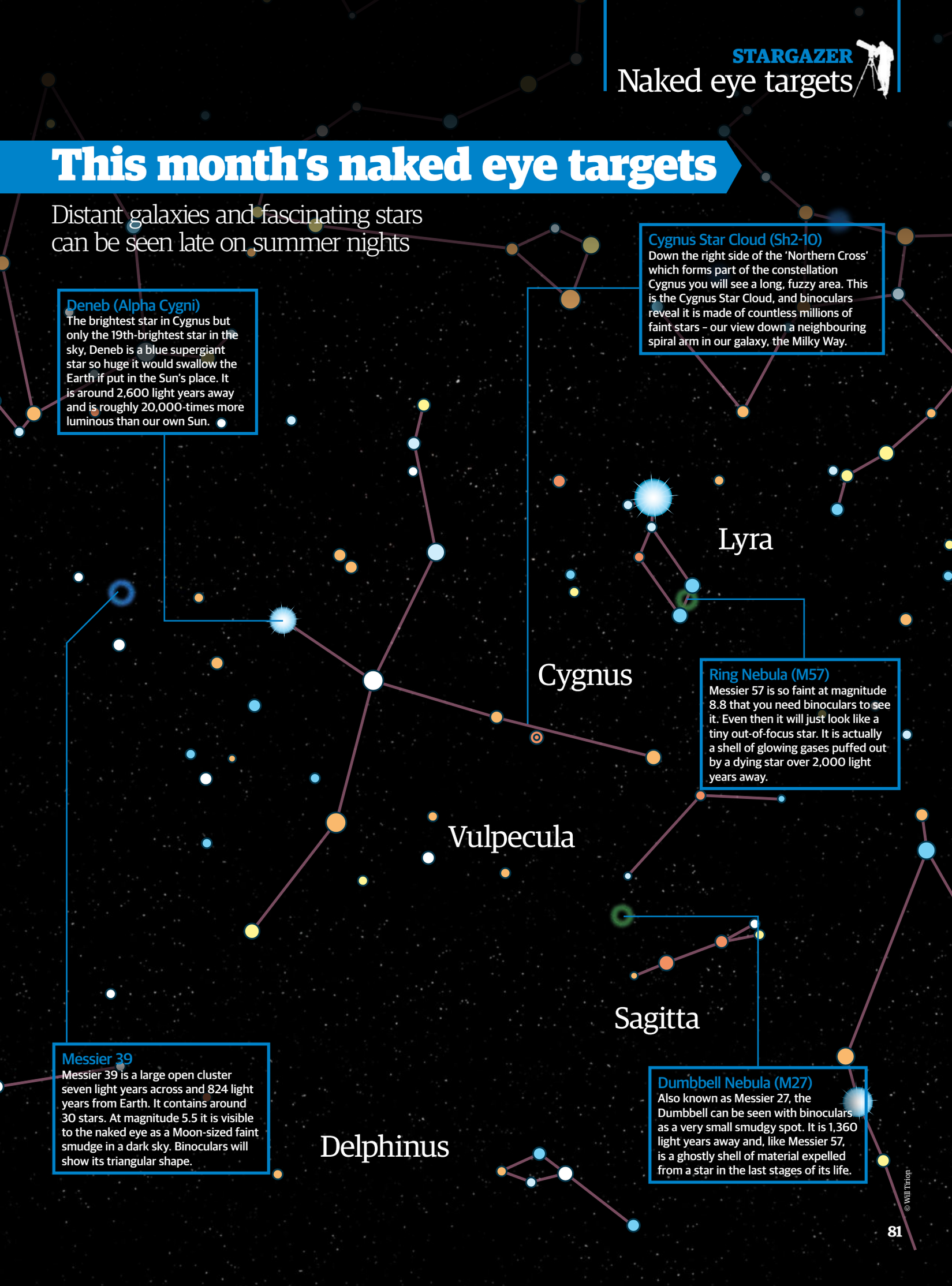
This month's lunar eclipse will be visible from many different countries, but unfortunately it will begin long before the Moon rises as seen from the UK, so we will miss the exciting moments of 'first contact' and the Moon entering totality. However, we will be treated to the amazing sight of a fully eclipsed Moon rising, which should be very striking indeed, so get to somewhere with a low and flat eastern horizon in plenty of time to watch the fully eclipsed Moon rising up like a hot air balloon. You can find out your location's moonrise time using various websites or apps.

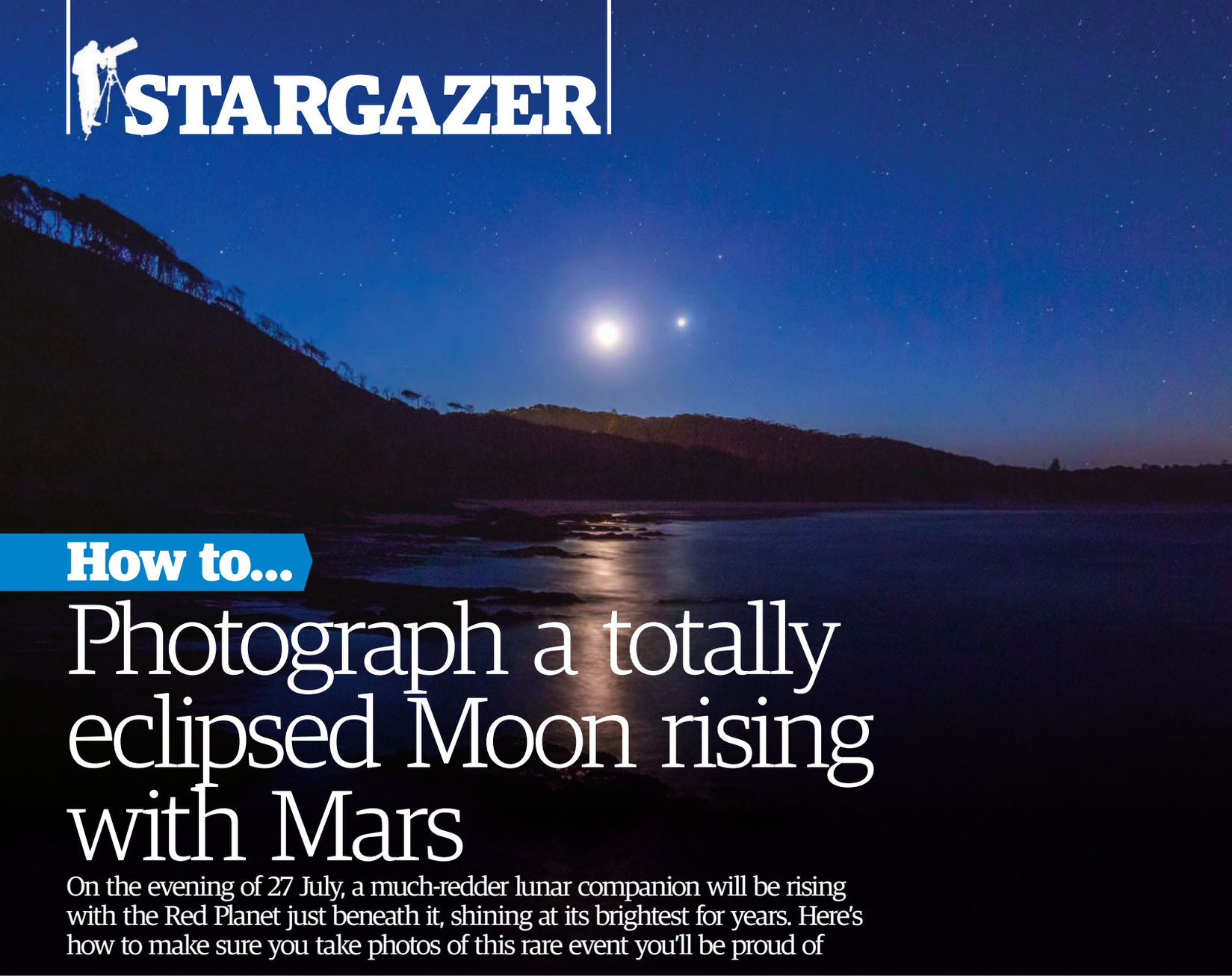
As an added bonus the Moon will be followed into the sky by the planet Mars, at its brightest for years, looking like a bright red 'star' to its lower right. Cross your fingers for a clear sky that night for the best views!

The eclipse will end at around 23:22, when the Moon will be its usual bright silver-white self again. But before then, hopefully we'll have had a great evening watching it drift silently through our planet's shadow.

This month's naked eye targets

Distant galaxies and fascinating stars can be seen late on summer nights





How to...

Photograph a totally eclipsed Moon rising with Mars

On the evening of 27 July, a much-redder lunar companion will be rising with the Red Planet just beneath it, shining at its brightest for years. Here's how to make sure you take photos of this rare event you'll be proud of

You'll need:

- ✔ A clear view to the south east
- ✔ A digital SLR camera
- ✔ A tripod
- ✔ Variety of lenses
- ✔ Computer with photo-processing software

Cross your fingers for a clear sky on the evening of 27 July. Not only will there be a total eclipse of the Moon, but Mars will look very striking in the sky too because it will be at opposition, closer to us and brighter in the sky than it has been for years. As if that wasn't enough, for a brief time we'll be able to see the totally eclipsed Moon and Mars shining close together in the sky, just above the horizon! Here's how to make sure you take great photographs of this very rare treat.

Look for an observing site well in advance, somewhere with a clear view to the south east, with no high buildings or hills to block your view. A few low trees will provide an attractive foreground for your photos.

Timing will be crucial, so be in place at least half an hour before moonrise on the big night so you have plenty of time to set up your camera and tripod. From the UK the Moon will rise already totally eclipsed (8:50pm London, 9:25pm Edinburgh) with Mars following some 40 minutes behind. Because totality ends at 10:15 there will only be a very small period in which you can capture the sight of the red, totally eclipsed Moon shining close to bright-orange Mars in the sky.

Set a time delay on your camera to reduce shaking it at the start of exposures, and make sure you have the correct ISO and exposure settings for your camera before things start happening; the last thing you want is to be frantically twiddling dials and pressing buttons when the Moon peeps over the horizon!

You'll be able to tell in advance exactly where the Moon will rise because the sky will start to brighten in that direction. Point your camera fitted with a zoom lens at that part of the sky, focusing sharply on any trees or buildings on the skyline to ensure the eclipsed Moon will be in focus when it appears. As the Moon rises, quickly adjust your camera so the Moon appears as big as possible and take various exposures of between one and four seconds.

Just before Mars is due to rise swap your zoom lens for a standard 50mm lens, so you can capture the eclipsed Moon and Mars in the same field of view (they'll be too far apart for a zoom lens). Try several different exposure times until your images clearly show the colours of both the eclipsed Moon and Mars. Changing to a wide-angle lens will let you take lovely images showing the pair surrounded by the pink summer sky.

Tips & tricks

Prepare well in advance
Find an observing site with a low south-eastern horizon. If it's flat, even better.

Get there early
Be in place at least half an hour before moonrise to ensure you don't miss anything.

Focus
Focus your camera on trees or buildings on the horizon in advance.

Set up your camera in advance
Make sure your camera's settings are correct before moonrise.

Keep checking
To avoid blurred photos check your camera's focus after every few frames.

Step away from the camera
Don't just take photos – make sure you spend time enjoying watching it!

Making the most of totality

You will need to take two different exposures and fit them together through image processing

Totality will officially end at 10:15, but the Moon will still look fully eclipsed for a while after that, so keep photographing the pair together as long as you can. After taking your photos, use image-processing software on your computer to make them sharper and enhance the colours of the Moon and Mars. However, don't overdo it and turn the Moon into a garish orange blob or Mars into a bright red dot.

Send your photos to
space@spaceanswers.com

1 Hunt for a clear south-eastern horizon

Scout out an observing site with a low south-eastern horizon, ensuring their are no tall hills or buildings to block your view.

2 Be prepared

Ensure your camera is set up well in advance – and you've taken test-shots - you don't want to miss the perfect photo opportunity.

3 Alter the focus

Check your camera's focus every few frames – lenses can move between shots and result in blurred photos.

4 Go for a wide-angle lens

Use a suitable lens to take scenic photos showing the sky and landscape, and a zoom lens for images of the eclipsed Moon.

5 Take time to just observe

Don't just take photos – make sure you spend time watching the eclipse and looking at Mars with your naked eye and through binoculars too.

6 Sharpen your shots

Use photo-processing software to improve your images, enhance the colours of Mars and the eclipsed Moon and bring out details.

Veil Nebula (Sharpless 103)

Deep sky challenge

Stars, clusters and nebulae of the summer

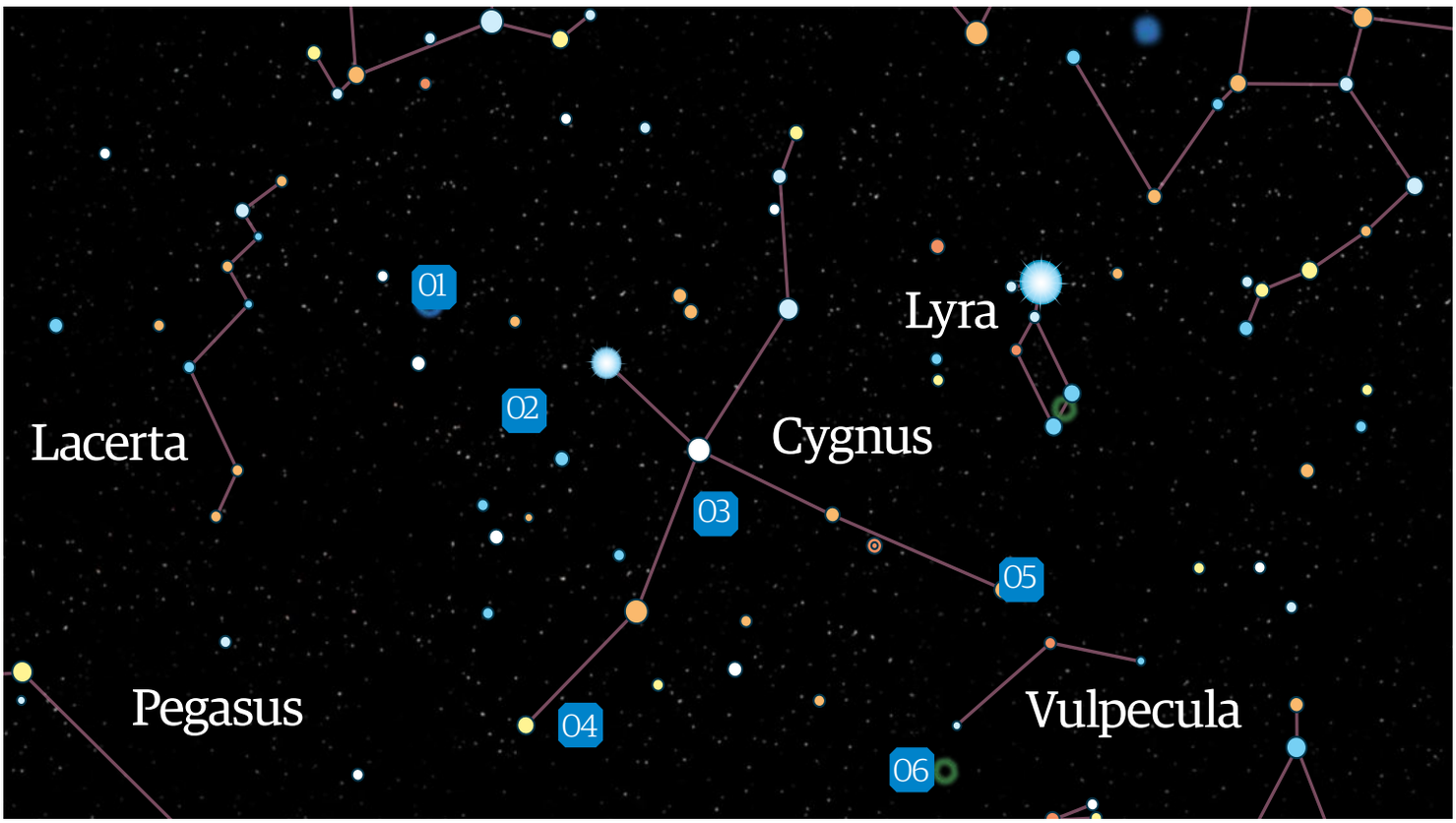
Glittering stellar groupings, a star's corpse and a beautiful double star can be seen through any size of telescope

Many think the summer sky is too bright to allow observation of 'faint' and 'fuzzy' deep-sky objects, but if you stay up late the sky is just dark enough to let you see some lovely sights. Around one and two in the morning – providing the sky isn't lit up with a display of bright blue and silver noctilucent clouds – a telescope will give you very pleasing views of some of astronomy's most famous objects.

Although the broad, frothy band of the Milky Way dominates the sky, running right through the centre of Cygnus the Swan, or the Northern Cross, cutting it and the whole sky in half, embedded in it are subtly coloured nebulae; regions where stars are being born. Elsewhere can be seen the ghostly remains of dying or dead stars and much more. Even a small telescope will give you a beautiful view of one of the loveliest and most popular double stars in the whole sky.

Don't be put off by the pessimists who claim that the summer sky is a write-off. As long as you don't mind losing sleep there's still lots to see.

Albireo (Beta Cygni)



1 Messier 39

Messier 39 is a loose open cluster, roughly triangular in shape and the same angular diameter as the Moon. It is best seen in small telescopes using low magnification.

2 North America Nebula (NGC 7000)

Although this famous emission nebula covers as much sky as around four full Moons, a telescope is needed to pick out its distinctive shape. Lower magnifications work best.

3 Messier 29

This magnitude 6.6 open cluster contains only a few scattered stars forming the shape of an open box. Small to medium telescopes pick it out well from the background sky.

4 Veil Nebula (Sharpless 103)

The 7th magnitude Veil Nebula consists of two arcs of faint gas, the remains of a star that blew up between five and eight thousand years ago. A medium aperture telescope will show structure.

5 Albireo (Beta Cygni)

One of the most beautiful double stars in the sky, any telescope splits Albireo into a 3rd magnitude gold star and a 4.7 magnitude sapphire-hued star, 20 arcseconds apart.

6 Dumbbell Nebula (Messier 27)

This famous nebula is just a smudge in small telescopes. Medium- and large-aperture telescopes show its twin lobes of blue-green gas. Larger instruments will show the star in its centre.

Messier 39

Wish Upon a Star in Sark

Take a trip to Sark and enjoy some of the most highly envied dark skies in the world

7-15 August 2018

In January 2011 Sark of the Channel Islands gained the distinction of being awarded International Dark-Sky Association recognition for its exceptional quality of unpolluted darkness, and became the first functioning island community to gain this title.

What does it mean? Sark, although very tiny, has a thriving population of around 600 people. We have everything this modern world can offer except motor cars and all they entail. This restriction means that our nights are truly dark, the planets of the Solar System easily distinguished, the stars a magnificent backdrop. Air quality is unsullied, sunsets and dawns spectacular, the Milky Way a brilliant belt strung across the heavens.

You do not need to be an astronomer to appreciate dark skies; they inspire poets, artists and lovers. However, if you are in any way, shape or form interested in what lies beyond our home planet, Sark is a place you will appreciate - and it's on your doorstep.

People who live under bright stars tend to take them for granted, a mere adjunct to all the other beauties of island life.

However, the less fortunate can hardly believe how amazing and awe-inspiring an unpolluted night sky can be. Their first visit to Sark can be, quite literally, an eye-opener.

Nights on Sark are very quiet, very dark and utterly peaceful. There are no street lights, and the light pollution which plagues stargazers who live in towns and cities is absent, so on looking up into the night sky it seems you can see a million billion stars.

In summer the nights are warm with a velvety black sky. At the height of summer the night is only six hours long, so stargazers have a limited time to appreciate the glories above. However, wandering around Sark's dark lanes in winter is a different experience, the pungent smell of wood fires replaces the sweet scent of honeysuckle. Orion the Hunter strides across the sky, the Milky Way sprinkles lights across the island. If time and trajectory are known, it is easy to spot the International Space Station passing overhead. Meteors, with their distinctive long tails, seem to pass quite slowly and may be visible for a few seconds. For those prepared to wrap up warmly and stay up there is a treat in store as the Earth could be showered in fireballs seeming to emanate from the constellation of Leo in November. Named the Leonids, this meteor shower is a wonderful display of shooting stars. A rare exception was 3,000 an hour being observed in some parts of Europe in 2002; nature's own firework show. The Perseids put on a similar show in August.

Every year for nearly 60 years

A favourite children's activity on Sark that's perhaps not so readily available elsewhere? With the lack of cars, slow pace and genuine small-community culture, children revel in the freedom of going places on their own, and even doing their first food shop by themselves, unaccompanied and unassisted.

Hmmm. Really?

While that might not sound very exciting, and perhaps even boring, there's a family that's been coming to Sark every year for nearly 60 years, staying anywhere from a couple of weeks to a month, now with generations of great-grandchildren, spouses, partners, cousins and friends in a huge extended family. There's been as many as 50 to 60 of the extended family on island all at one time! And having talked personally to many of the children, from 5 to 14 years old, they say they will always come to Sark every year, always.

How to get there

Travelling to Sark must be by boat from Guernsey or Jersey, which in turn can be reached by air or ferry. For full details, go to **sark.co.uk**, e-mail office@sark.co.uk or call 01481 832345

Hundreds of meteors on Sark!

When will there be hundreds of meteors?
Each year the Perseid Meteor shower occurs from around 17 July to 24 August. During that period there is usually a peak, and sometimes more than one, with an increased number of meteors. Often this is around the 12 August, and on rare occasions a peak could become an 'outburst' with many more meteors, as in 2016. This year the Perseid meteor peak is anticipated one day after a new Moon, so the sky will be especially dark.

Will there really be hundreds?
The number of meteors gradually increases as the anticipated peak occurs, averaging from 40 to 80 per hour, increasing to as many as 110 to even 140 an hour. While these are theoretical rates and include the very faintest, over a period of a few hours it should be possible to see several hundred meteors given clear skies.

What else will be happening besides the Perseids meteor shower?
Between 7 to 15 August, Professor Ian Morison and author Robin Scagell will be on Sark giving evening talks on a wide variety of topics and guiding telescope observation sessions. Public viewing will be available during the day with a solar telescope, and evenings with an 8-inch Meade with motor drive and Go To, a 12-inch Dobsonian and the 10-inch Meade at the Sark Observatory.

This Perseids meteor shower peak sounds special, does it happen all the time?
The next time the Perseids peak when it's a new Moon is 2026, eight years from now, so yes this year is a bit special, and a good time if you have ever had a dream to 'Wish Upon a Star' in Sark. The planets Mars, Jupiter and Saturn will all be on show, and with the new Moon we can observe a wide range of star clusters, nebulae and galaxies to be decided at the time.

Sometimes astronomy and telescopes sound technical – what if I'm new to astronomy?
No experience is necessary to enjoy stargazing, with expert guides Ian Morison and Robin Scagell. Ian is a keen amateur observer and is an expert on taking photographs through amateur telescopes. Ian's career at the Jodrell Bank Radio Observatory involved him in many exciting projects. Robin Scagell was given the Sir Arthur Clarke Award for Space Reporting, has authored many popular astronomy books and even has an asteroid named after him!

Why go to a Dark-Sky location? Won't I see meteors where I live?
The Perseids are famous for a higher number of fireballs, so bright they can be seen during the day. You can see some meteors where you live, but it might take a while of vigilant watching. More faint meteors can be seen in darker skies, so the darker the skies, the more stars to 'Wish Upon'! Even better, on a Dark-Sky Island location like Sark, distinct meteor colours and the full extent of the meteor tails are visible.

Why Sark? Can't I just go to a dark area close by?
Light pollution affects a surprisingly large area. Sark has some of the darkest skies in the British Isles, Bortle Class 3, with some dark-sky readings that qualify for Bortle Class 2. There are only two other places in the British Isles with skies as dark as Sark, in remote areas of Scotland.

This sounds great! So where do I stay on Sark?
Camping outdoors is ideal for meteor-watching, giving you a perfect view of all the stars. So if you want to make the most of your stargazing experience, book at one of Sark's two campsites on **sark.co.uk**. The island also provides a safe environment for children who enjoy seeing the universe, but places are limited, so don't wait to book to 'Wish Upon a Star in Sark', between 7 to 15 August, - you're in for a blockbuster astronomy week!

Events

Since our first Starfest celebration in October 2011, SAstroS has hosted two such events a year in autumn and spring. This year come join us to 'Wish Upon a Star in Sark' Perseids Meteor shower, 7 to 15 August, joining Professor Ian Morison and author Robin Scagell for talks and nighttime observations. Previously we have welcomed guest speakers, including:

Professor Andrew Coates, head of planetary science at Mullard Space Science Laboratory

Dr Marek Kukula, public astronomer, Greenwich Royal Observatory

Dr Chris Linott, Oxford University and presenter of BBC Sky at Night

Inspiration

Be inspired to come dream with us to 'Wish Upon a Star in Sark' during the Perseids Meteor shower, 7 to 15 August, joining Professor Ian Morison and author Robin Scagell for talks and night-time observations. Sark is the Dark-Sky Island inspiration for Enya's album of the same name, and the new book *Sark in the Dark: Wellbeing and Community of the Dark Sky Island of Sark* by Ada Blair. *National Geographic Traveler* magazine chose Sark as a top 20 must-see destination in 'Best Trips' in 2015.

The Northern Hemisphere

Galaxies, nebulae and star clusters grace the August skies, offering an exquisite selection for stargazers

July sees the opposition of the Red Planet, but heading into the following month, there's an impressive array of targets suitable for observers armed with binoculars, telescope or of which are just content with gazing upon the night sky with the unaided eye.

Galaxies and star clusters are abundant, however, it's the nebulae within constellations such as Cygnus and Lyra that are the objects to look to this month. The Ring Nebula (M57), the Pelican Nebula, young and dense planetary nebula NGC 7027, reflection nebula NGC 6914 and the 'blinking planetary' NGC 6826 are particularly impressive, providing observing and imaging opportunities for astronomers and astrophotographers alike.

Using the sky chart

This chart is for use at 10pm (BST) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

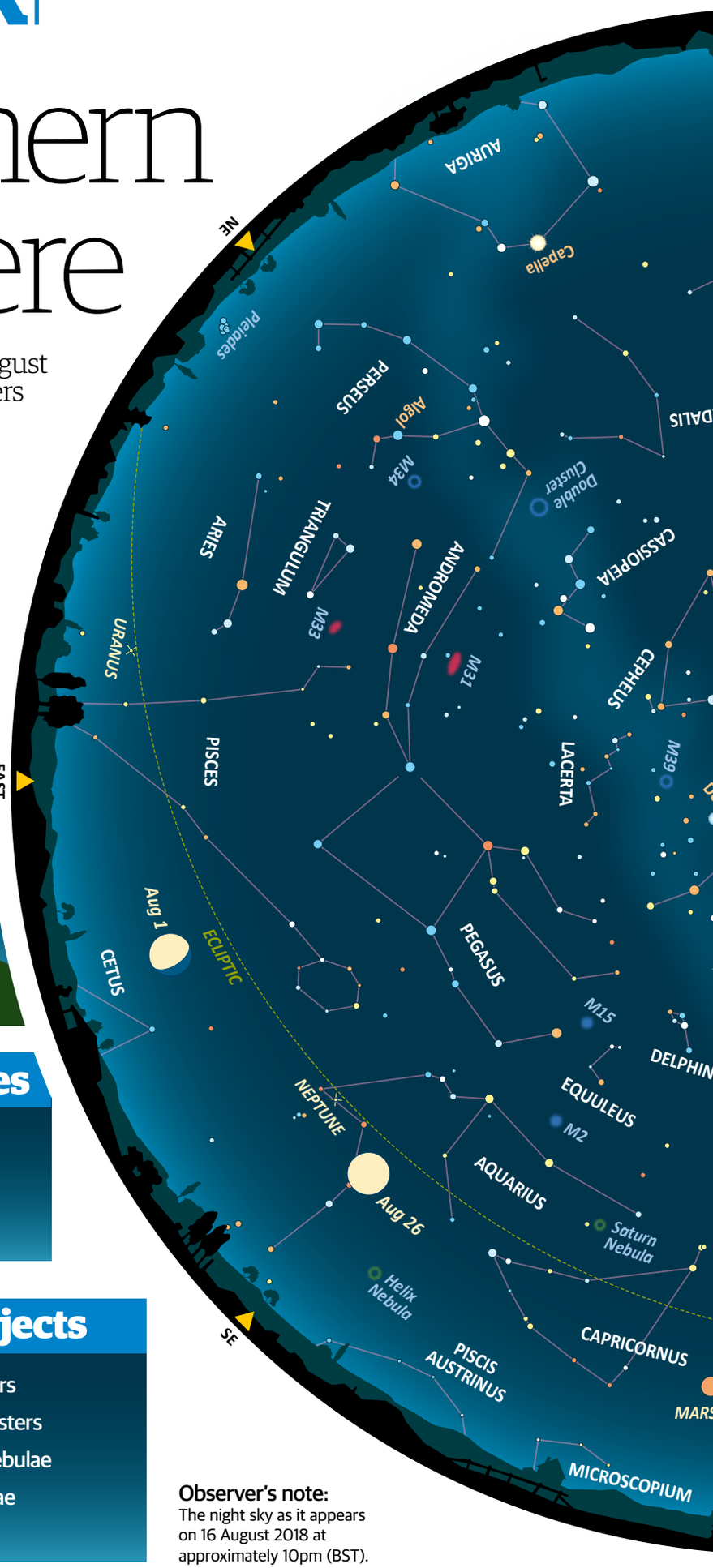
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

- O-B
- A
- F
- G
- K
- M

Deep-sky objects

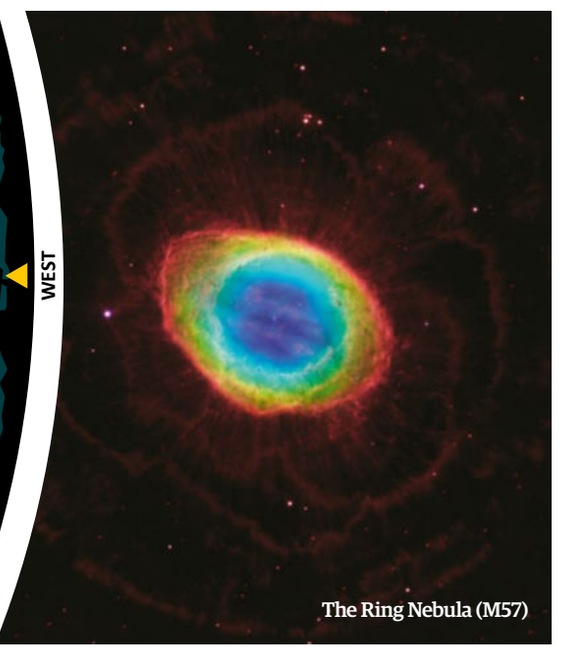
- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note:
The night sky as it appears on 16 August 2018 at approximately 10pm (BST).

The Northern Hemisphere

Messier 56



The Ring Nebula (M57)

NGC 6914

Astroshots *of the month*

Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**

Peter Louer

Teide National Park, Tenerife

"I retired to the beautiful island of Tenerife in 2013. One of the top sites in the world for astronomy, the Caldera in Teide National Park is at an altitude of over 2,000 metres, with a dry atmosphere and limited light pollution. It has proven to be the ideal location to combine my hobbies of photography and astronomy – here's our stunning galaxy, the Milky Way."

Messier 61

Warren Keller

Buckhannon, West Virginia

Equipment: 16-inch RCOS Ritchey-Chrétien owned by the University of North Carolina PROMPT2 at Star Shadows Remote Observatory (SSRO) at CTIO

"Here's Messier 61 in Virgo, a seldom-seen galaxy and one of the largest galaxies in the Virgo Cluster, a massive group containing more than 1,300 members. With a spatial diameter of 100,000 light years, this face-on island universe lies at a distance of 52,000,000 light years from Earth. This data was acquired in 2018 by my partners at the Star Shadows Remote Observatory.

"Also for your viewing pleasure are NGC 6164 and NGC 6165 in the constellation Ara, a gorgeous bipolar nebula that surrounds the extremely rare O6.5f-type star, designated HD 148937. The central nebula is estimated to be about 4,000 light years from Earth. This data was acquired in 2018 by SSRO and the final image is a collaboration between myself and my SSRO partners."

Our galaxy, the Milky Way

NGC 6164 & 6165

Anvar Ghaderi

Western Azerbaijan, Iran

"I'm an astrophotographer and enjoy shooting nightscapes, in particular the Milky Way and Iridium flares, framed by the stunning landscape of western Azerbaijan. Here you can see Iridium shine above the Hama ship at Lake Orumieh."

An Iridium flare above the Hama ship at Lake Orumieh

Send your photos to... @spaceanswers space@spaceanswers.com

Altair Astro 60 EDF

Portable and devoid of colour-fringing when observing bright targets, this doublet refractor is any astronomer's dream

Telescope advice

Cost: £399 (approx. $525)
From: Altair Astro
Type: Refractor
Aperture: 2.4"
Focal length: 14.17"

Thinking of booking a late holiday this year to somewhere abroad with dark, clear skies? Then as the dedicated astronomer you are, you'll want to take a 'scope with you. It'll need to be small and light so as not to exceed your baggage allowance, while at the same time have great optics so that you can make the most of those dark skies.

Altair Astro have the perfect 'scope for you: the Altair 60 EDF, which they are calling their lightest, most compact telescope yet. The telescope tube weighs just 1.5 kilograms and is 23cm in length – your socks will take up more room in your luggage! As such, the 60 EDF makes for a spectacular grab-'n'-go telescope for day- or night-time observing.

It is, of course, the night-time observing that we're most interested in. What's really interesting about the 60 EDF is the coating on its lenses. Refracting telescopes use lenses to focus the light to a point, but this results in a phenomenon known as chromatic aberration or 'colour fringing'. Lenses focus different colours (wavelengths) of light slightly differently so that they don't all arrive at exactly the same focal point. This can result in fringes of colour around the celestial object that you are observing. To minimise the chromatic aberration two lenses are used, one convex, the other concave, together forming a doublet lens element that can modify how different colours of light are focused so they arrive at the same focal point, counteracting the chromatic aberration.

The vast majority of refractors these days are doublets – some are even triplets – but what makes the 60 EDF interesting is the coatings on its lens element. The 60 EDF uses coatings of synthetic fluorite, known as S-FPL53. These coatings give the

The refractor uses synthetic coatings that reduce colour-fringing

lens element extra-low dispersion properties (hence 'ED' in the 'scopes name), reducing chromatic aberration even further. S-FPL53 is used in Altair Astro's celebrated 125 EDF APO refractor, but you can experience it here in the 60 EDF for a much lower price. And boy, does it work well!

Testing was done during the summer months here in the UK, so sadly we didn't have the perfectly dark skies that you may be craving when travelling abroad. Nevertheless, there was still plenty to observe. Venus, a shining evening star, showed its gibbous phase clearly and obviously, with barely a hint of colour fringing thanks to the 60 EDF's lens element. Switching eyepieces to view a first quarter Moon, the dark plains of Mare Tranquillitatis (the Sea of Tranquillity, Apollo 11's landing site) and Mare Serenitatis (Sea of Serenity, Apollo 17's landing site) contrasted nicely with the older, more cratered highlands, with the vast blast mark of the crater Copernicus deep in early morning shadow.

Turning towards the stars later in the evening, the 'scope's wide field of view became obvious. Slewing through the Milky Way as it ran through the Summer Triangle was a joy to behold. Ramping up the magnification to 120x, and with a bit of patience in the not-completely-dark sky, all four members of the 'Double Double – Epsilon Lyrae – were visible, brought into focus by the excellent dual-speed 1:10 rack and pinion focuser. The focuser is nothing fancy, but it works wonderfully smoothly, with 75mm of drawtube travel.

There are of course limitations to a telescope just 60mm in aperture. We weren't able to resolve the stars of M13, the Great Globular Cluster in Hercules, while the Ring Nebula was barely a smudge of light, its doughnut-shape not evident.

Of course, affix the 60 EDF to a good tracking mount such as Vixen's Polarie or the AstroTrac, and imagers will have no problem getting great pictures of these deep-sky objects, particularly the larger clusters and galaxies more suited to the telescope's wider field.

> "Turning towards the stars later in the evening, the scope's wide field of view became obvious"

It's with imaging that one of the 60 EDF's more novel characteristics comes into play, namely the Camera Angle Adjuster (CAA) at the back end of the telescope. This allows your camera to rotate to better frame your target on the imaging sensor, resulting in more picturesque images. It's particularly handy for imaging planets, since refractors produce upside-down images that turn south up and north down on planets. The CAA lets you negate this by simply turning the camera around. Triple-locking thumbscrews make sure that your camera is held in place securely.

As with all Altair Astro telescopes, its lovely white-and-black livery with a splash of red on the focuser, lens cap and around the rim of the dew shield, which when extended gives the scope a length of 30cm, looks rather pretty, and what you get in such a small package is admirable.

Be warned, despite its small size the 60 EDF is not a beginner's package. For one, it doesn't come with any eyepieces or a diagonal, so a purchaser either has to buy them separately or use ones they already own, which a beginner is unlikely to have. The visual views through a 60mm aperture also limit the observer in what they can see – imagers will get far more out of the 'scope. But the crystal-clear views through the optics and ease of use make the 60 EDF a winner in our eyes.

Best for...

- Intermediate
- Medium budget
- Planetary viewing
- Deep-sky objects

A rotating rear collar with locking screws allows you to frame an object perfectly

Clear, sharp views were had, thanks to the sensitive focuser

The 60 EDF features a 2" to 1.25" eyepiece adapter

A 3-in-line hole allows for attachment with most mounting systems on the market

WIN!

AN ASTRONOMY BACKPACK BUNDLE, INCLUDING A MEADE ADVENTURE SCOPE

Make observing from any location a breeze with our latest competition

WORTH OVER £100

This pair of portable astronomical products make for the most ideal grab-and-go bundle. The Meade Adventure Scope, courtesy of Hama UK Ltd, is a lightweight refractor with an 80-millimetre (3-inch) aperture. Complete with a tripod, a red dot finder, two eyepieces and its very own backpack, there is everything you need to pick up your kit and observe the night sky from whichever location that takes your fancy. Its optical system provides excellent sights of a variety of targets from the rugged surface of the Moon, to some of the brighter planets and deep-sky targets.

To help you get started, we have included Phillip's *Stargazing with a Telescope*. This guide will usher you through what celestial objects there are to observe, providing you with a rich understanding of observational astronomy.

What's more, *Stargazing with a Telescope* will help you decide on what telescope you should upgrade to, ensuring you have seamless guidance in your hobby.

To be in with a chance of winning, all you have to do is answer this question:

What was the first spacecraft to orbit Venus?

A: Akatsuki B: Venus Express C: Venera 9

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Congratulations to Alan Bowen, who is the winner of the Celestron 114 LCM telescope

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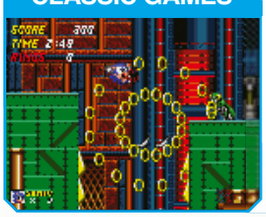				

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Book Photographing the Deep Sky: Images in Space and Time

Cost: £20.00 (approx. $26.50) **From:** Pen & Sword Books Ltd.

Being aware of author Chris Baker's astroimages, we were excited to get our hands on his book to feast our eyes on more of his exquisite work. We were not disappointed - there are a multitude of pictures showing nebulae, galaxies and other celestial wonders, revealing the many exuberant colours and fine details that can only be imaged with a great-quality telescope.

The pages of *Photographing the Deep Sky* offers excellent advice on how to image all kinds of targets and is packed with information on telescopes, filters and tips and tricks on imaging far-flung objects. Details on these deep-sky targets in more of a scientific sense are also included, where Baker briefly explains the nitty-gritty theory behind the objects. Although the pictures are glorious, and the fine glossy paper really emphasises them, we believe there could have been more text to describe the accompanying images in much more enticing detail. This is the only criticism of this book, since the main appeal are its images, not really dampening any enjoyment of the stunning astronomical sights printed on its pages.

Accessories Explore Scientific 11mm 82° Eyepiece

Cost: £133.00 (approx. $176.00) **From:** Rother Valley Optics Ltd.

Our overall impression was extremely positive and we consider this eyepiece - from the independent Explore Scientific - great value for money. If you're spending long hours observing, then you'll need an eyepiece that is mainly two things: has good quality optics which return the best views possible and is comfortable to use.

The eyepiece's design affords the observer both of these traits, allowing them to get the most out of an observing session. As for the eyepiece's optical capabilities, it returned crisp and clear images and would resolve any object we turned our telescope to - notably excelling with brighter objects in the sky such as the Moon and Jupiter, returning breathtaking views. It is important to note that the manufacturers recommend this eyepiece to be used with telescopes that have a focal ratio of f/5 and above, meaning that it is best suited for more wide-field observations, such as those of galaxy and star clusters.

The price may appear costly to the beginner, but as an experienced astronomer it can make or break a good observing opportunity. With a strong and comfortable design along with great optics, we would recommend Explore Scientific's latest offering to the more seasoned astronomer.

App SkySafari 6 Pro

Cost: £38.99 (approx. $50.00) **For:** iOS

This is the ultimate astronomy app in our opinion. The pricetag is hefty, but what you get is an unprecedented amount of information with an enjoyable interactive interface of stars, planets, galaxies, nebulae and more. However, there is a downside to SkySafari 6 Pro: there is so much to this package that it takes up just shy of two gigabytes of your storage - sadly a bugbear for those who don't have enough memory on their device.

Not only is its database vast, but it is also designed to help you with your observing sessions. Its planetarium system, which can be switched to red light in order to preserve night vision, can help you navigate around the night sky and find your intended objects. It can be used to control a telescope as well, slewing to your target without even having to touch your instrument.

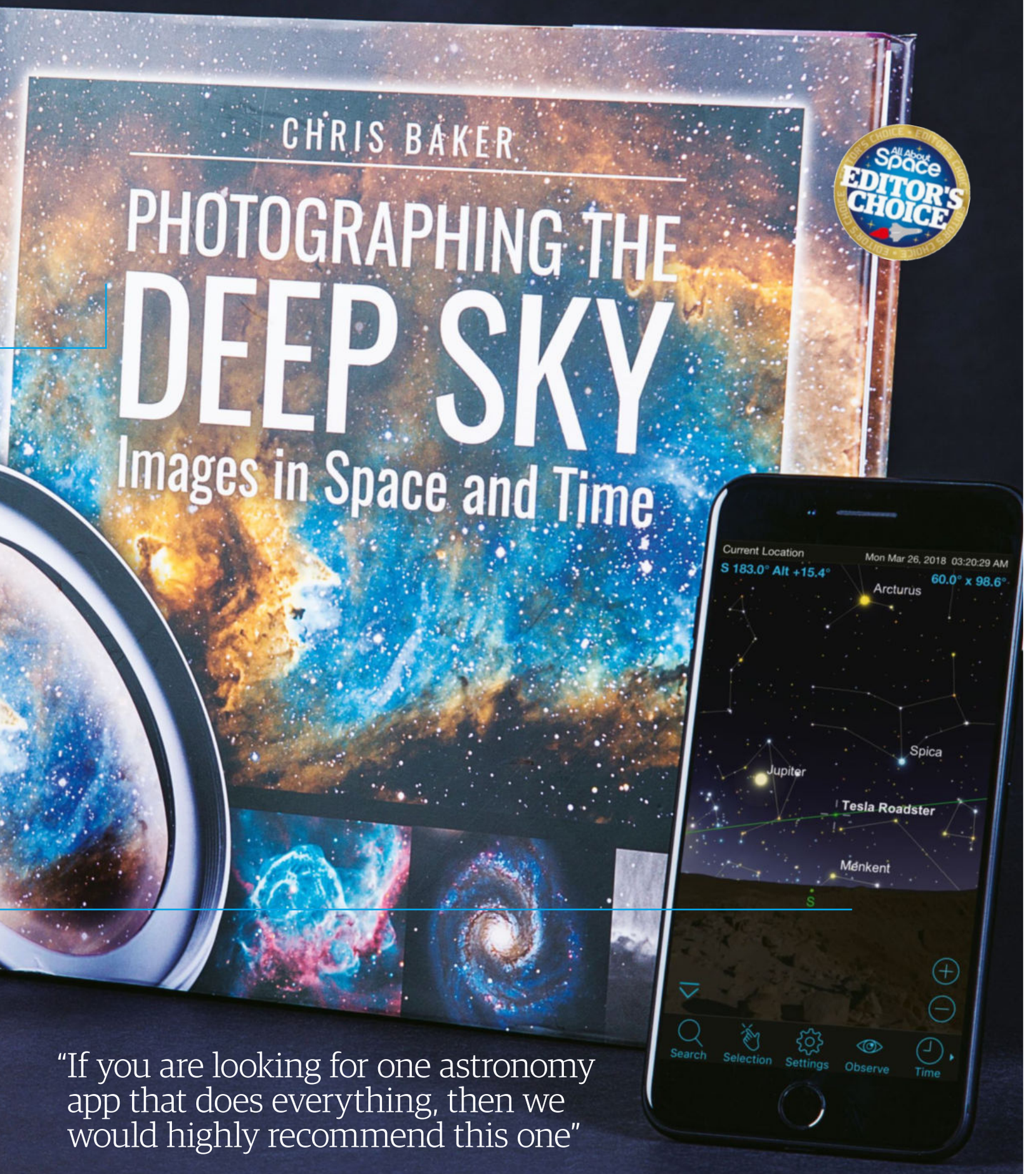
The capabilities of this app are endless (we advise you have a play on a trial version!), so if you are looking for one astronomy app that does everything, then we can't recommend SkySafari 6 Pro enough.

Accessories Celestron TrekGuide

Cost: £22.00 (approx. $29.00) **From:** Celestron

A digital compass, thermometer and clock all condensed into this pocket-sized device. Lugging around equipment including heavy telescopes, mounts and tripods can be a massive nuisance, so anything that is compact, light and useful is extremely welcomed. The TrekGuide is powered by two CR2032 Lithium batteries and will help you on your navigation and preparation ahead of a night's observing. Built into the TrekGuide is a bubble level that will come in handy when setting up your telescope to ensure a proper construction.

The compass is most useful in the alignment process of a telescope to ensure it's pointing towards the north or south star, depending on which hemisphere you are located. The other aspects, such as temperature, time and so on are more for a general overview of the night. Testing the device tells us that it does the job - and you won't get lost when wandering through the countryside trying to find the best spot for night-sky observing.



"If you are looking for one astronomy app that does everything, then we would highly recommend this one"

Alan Bean

He became the fourth man to walk on the Moon during the Apollo 12 mission

Moon-walking astronaut turned talented artist, **All About Space** looks back at the fantastic life and career of Alan Bean after he recently passed away on 26 May 2018, at the age of 86.

Born on 15 March 1932 in Wheeler, Texas, United States, Bean always wanted to be a pilot from a young age. After considering the career paths that could lead him to his dream job, Bean joined the Naval Air Reserves in high school. This led him to become a test and fighter pilot around the same time NASA's space programme was coming into fashion. On his second attempt of applying to become an astronaut, Bean was finally accepted as part of the third group of astronauts ever selected by NASA in October 1963. This group included fellow Moonwalkers such as Eugene Cernan, David Scott and Buzz Aldrin. Before he went to space, Bean served as a backup for crew members on Gemini 10 and Apollo 9.

On 14 November 1969, Bean's time had come to leave the constraints of Earth as he was given the role of Lunar Module pilot on the Apollo 12 mission. Along with Pete Conrad, the commander, and Richard Gordon, the Command Module pilot, these three astronauts went to the Moon for the second time in the history of humanity. During the space of ten days, Bean became the fourth man to walk on the Moon while also demonstrating that NASA is capable of achieving pinpoint landings on the lunar surface, collecting parts of the Surveyor 3 lander and also deploying the Apollo Lunar Surface Experiments Package (ALSEP).

Four years later Bean returned to space for a second stint, but this time he was the commander. Along with science pilot Owen Garriott and pilot Jack Lousma, the trio participated in the second manned mission to the first space station built by the United States, Skylab. This mission, labelled Skylab 3, lasted almost six-times longer than Apollo 12 and achieved 150 per cent of its scientific goals, while also showing how feasible it was to stay in space for roughly two months. This mission drew Bean's time in space to an end, having logged 1,672 hours in space, with approximately ten-and-a-half hours being EVAs (Extra-Vehicular Activities).

Towards the later stages of his NASA career Bean served as a backup spacecraft commander for the United States-Russia collaborative project known as the Apollo-Soyuz Test Project in July 1975. After retirement Bean then focused on his painting, recreating the amazing sights he had seen.

He stated that based on his 18-year astronaut career he had seen things no other artist could have seen before, and hence wanted to capture those experiences through his art. His art is also in the company of the many personal achievement awards that he has received over the years, including the Distinguished Service Medals from NASA and the Navy, among many others.

Alan Bean was Lunar Module pilot for Apollo 12

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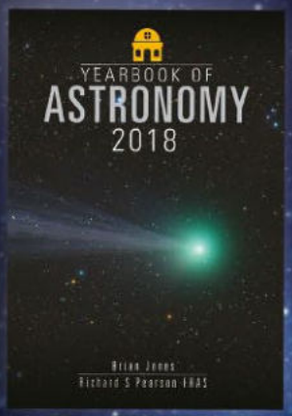

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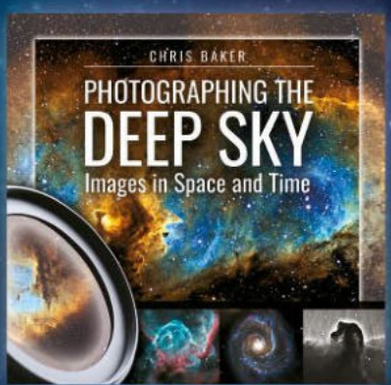

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